Designing to Prevent Corrosion*

By R. B. Mears and R. H. Brown*
Aluminum Company of America, New Kensington, Penna.

IN DESIGNING structures or equipment, first consideration is usually, and should be, given to fulfilling the mechanical or physical requirements. It is of fundamental importance that the article being designed will have sufficient strength to withstand the service conditions during its initial period of use. However, it is also usually desired that the article remain in serviceable condition for some minimum period of time. Thus, factors which are functions of time must generally be taken into consideration. Factors of this type are fatigue, creep, certain metallurgical transformations, and corrosion. Of all of these factors, corrosion is probably the one most difficult to take into account. This is because the specific conditions of the service often greatly affect corrosion rates; and these specific conditions are frequently not known, or their importance is not appreciated, in advance.

Because corrosion is a complicated problem, frequently no specific steps are taken by the design engineer in protecting against corrosion hazards. At best he may increase the section thickness over that dictated by mechanical considerations if the expected conditions of exposure are deemed by him to be corrosive.

However, even though it is often difficult to evaluate at all accurately in advance the corrosivity of a specific service, certain fundamental precautions which apply to nearly all service applications can be incorporated in the initial design. In order to understand reasons for taking these precautions, it is well to review present knowledge on the mechanism of corrosion.

Mechanism of Corrosion

Corrosion is the reaction of a metal (or possibly of non-metallic materials also) with its environment. It is generally considered that this reaction can be either direct or indirect. The direct reaction can be termed "chemical corrosion" and the indirect one "electrochemical corrosion." As an example of direct corrosion, the reaction of sodium with hydrochloric acid may be given. This can be written as

(1) $2\ Na + 2\ HCl = 2\ NaCl + H_2$.

Since this process is generally con-

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* Now manager Tin Plate Research Laboratory, Carnegie-Illinois Steel Corporation, Pittsburgh, Penna.

sidered to involve electron interchange, it may also be symbolized as:

(2) $2\ Na + 2H^+ = 2\ Na^+ + H_2$.

This equation can be broken down into two steps indicated by

(3) $2\ Na = 2\ Na^+ + 2\ e$, and

(4) $2\ H^+ + 2\ e = H_2$

where e indicates an electron. When equations (3) and (4) are combined, they give equation (2).

When the reactions expressed by equations (3) and (4) occur at the same area of the metal surface, the corrosion which occurs may be termed chemical corrosion; when these reactions occur at areas which differ by some finite or measurable distance, the corrosion is said to be electrochemical.

In the case of iron,[1] or most of the common metals[2, 3] exposed in neutral or nearly neutral aqueous solutions, the reactions do occur at areas separated by appreciable distances. Therefore, most of the corrosion commonly encountered in service is of the electrochemical variety.

The area of the metal surface at which a reaction of the type illustrated by equation (3) occurs is termed the anode. The area at which a reaction of the type indicated by equation (4) occurs is termed the cathode. The principal practical advantage accruing from a knowledge that the corrosion of most commonly used metals under most usual service conditions is electrochemical is that in some cases the environmental conditions can be altered slightly, as by treating a liquid corrodent with an inhibitor, so that either the anodic or cathodic reaction is retarded. Interference with either of these reactions slows down the overall corrosion process. This will be discussed in more detail later in this paper.

Where corrosion is electrochemical, it is evident that there must be come local difference between anodic and cathodic areas, or else the same reaction would occur at both areas. It has been found that the solution potential of these areas, when measured separately against a standard reference half cell, differs appreciably. In fact, it has been rather conclusively demonstrated that unless the open circuit solution potentials of these local anodes and cathodes differ appreciably, no electrochemical corrosion will occur. In other words, a perfectly homogeneous metal in a perfectly homogeneous environment would not corrode electrochemically. Unfortunately, under service conditions neither the metals nor their environments are homogeneous.[4]

The designer has little control over the homogeneity of the metals which will be used. It is, therefore, fortunate that under most service conditions inhomogeneities in environment normally are more important sources of potential differences and, therefore, of corrosion than are inhomogeneities in the metals employed.

In service, probably the most serious source of corrosion cells resulting from local potential differences is caused by concentration cells. If one portion of a metal surface is in contact with a dilute salt (or acid) solution, and another portion of the same surface is in contact with a concentrated solution of the same material, a difference in potential between these two areas results. If there is a conducting path through

the liquid, electric current will flow between the two metal areas, and electrochemical corrosion of one area will occur. Such corrosion is said to result from concentration cells.

A special case of concentration cell is the oxygen concentration cell. This is caused by local differences in the oxygen concentration in various parts of the liquid contacting a metal surface. In this case, the metal surface which contacts the solution containing the smaller amount of dissolved oxygen is the anode. This surface corrodes; but that surface contacting the solution containing more oxygen is the cathode and is partially or completely protected. For many metals, oxygen concentration cells are probably the main source of corrosion under service conditions.

Corrosion cells can also be set up by local differences in temperature, agitation, illumination, liquid velocity and, in fact, by almost any heterogeneity in exposure conditions.

Next to concentration cells, cells caused by the contact of dissimilar metals (or alloys) are probably the most common causes of severe corrosion in service. Corrosion caused by contact between dissimilar metals is termed galvanic corrosion. The effects produced by and the methods of alleviation of galvanic corrosion have been discussed in articles published in previous editions of this journal.

Distribution of Corrosion

In evaluating the extent of corrosion, it is common practice to measure the weight of metal lost or corroded away, and to calculate the corrosion rate as loss in metal in milligrams per square decimeter per day or in inches penetration per year. This is a reasonable measure of the total extent of the corrosion reaction. However, in many cases, it does not indicate the extent of the damage resulting from corrosion. For instance, of two metals showing the same weight loss after some specific exposure, one may have been attacked uniformly over its entire surface, while the other was virtually unattacked over most of its surface, but was perforated by highly localized corrosion at a few small areas. If the desired use was as a storage tank or shipping container, the material which developed the localized attack or pits would be much less suitable than the material which developed uniform attack. For many structural applications, the material which pitted might be just as satisfactory as the other material.

Thus, for many applications it is just as important to know the depth of the deepest pits as to know the average over-all extent of corrosion.

In addition to pitting, there are other types of localized corrosion. A metal may develop blisters at local areas, or it may be attacked selectively at grain boundaries or along slip planes. If it is a two-phase alloy, one phase or constituent may be attacked selectively, while the other or others are completely resistant. The occurrence of localized attack often makes it difficult to evaluate the true extent of the corrosion damage.

Localized attack can result from the conditions of exposure as well as from the metallurgical structure of the material. It is inherent in the electrochemical mechanism of corrosion that at certain areas, the

anodes, metal is attacked, while at others, the cathodes, little or no attack may occur. If environmental conditions set up potential differences between various areas of a metal surface, localized attack is almost certain to occur.

Interfaces between different phases, such as the air-liquid boundary, are often sites of special attack. Often corrosion will occur at the "water line" and no place else. In most cases such selective attack is electrochemical in nature and is caused by local cells set up by differences in oxygen concentration.

Interfaces between non-metallic materials such as wood, glass, and the like can also be the sites of local attack. Here also differences in oxygen concentration in the liquid layer in the crevice between the metal and the non-metal, as compared to the oxygen content in the body of the liquid, are frequently the cause of the corrosion. Contact between wet porous materials, such as cork, paper, cloth, leather, etc., is likely to be particularly undesirable, since local attack at the interface is especially likely to occur.

Effect on Environment

In some cases the effect of the materials of construction on the products being handled must be considered. Thus, in designing equipment for handling foods or chemicals, it may be more desirable to select a material which has white or colorless corrosion products than to use a more resistant material with intensely colored corrosion products. Similarly, in the case of food products, materials of construction for equipment should be selected which do not change the odor or flavor of the foods and which do not form toxic compounds upon contact with the food. Finally, in some cases, certain materials of construction may be relatively resistant to the product to be handled but may catalyze its decomposition.[5] In such cases catalytically inactive materials of construction should be selected.

As a special case, in some cases where contamination of the product is not an important consideration, voluminous corrosion products may prove undesirable because of interfering with heat transfer, plugging tubes, screens, valves or for other reasons.

Therefore, it is generally necessary to consider the effect of corrosion or reaction of the construction materials on the products being handled, even though insufficient attack will occur in service to cause structural damage to the equipment.

Galvanic Corrosion

The possibility of galvanic action between dissimilar metals is now rather widely known. An example of a type of a galvanic cell which is not uncommonly encountered is shown in Figure 1. The aluminum coil makes a direct metal to metal contact with the copper tank. In most aqueous solutions aluminum is anodic to copper, and hence current flows from the aluminum through the solution to the copper and returns by the metallic path. As a result the aluminum will suffer from galvanic corrosion and the coil will be prematurely perforated. The lower sketch shown in Figure 1 is an example of the type of cell which may be set up in the laboratory to study some of the effects that would

be produced by corrosion in this type of assembly.

It is not such common knowledge that the potentials of any one metal or alloy differ widely, depending on the nature of the environmental conditions. The reversible potential of a metal in the electromotive force series is only a rough guide to its galvanic behavior in any specific solution. A metal which one would predict from the electromotive series to be seriously attacked may actually be protected, whereas the other metal of the couple would suffer galvanic corrosion.[6] If the composition or nature of the solution is altered, the relative potentials of the different metals are also altered.[6] Thus, in one solution zinc may be anodic to steel, while in another solution the relative potentials of these two materials may reverse. In another case, the potentials of two metals may be practically the same in a sodium chloride solution, but in a sodium sulfate solution they may be quite different. For this reason, in the absence of specific information to the contrary, it must always be assumed that the use of dissimilar metals in a structure which will be exposed to moisture or aqueous solutions will result in special galvanic corrosion of at least one of the dissimilar metals.

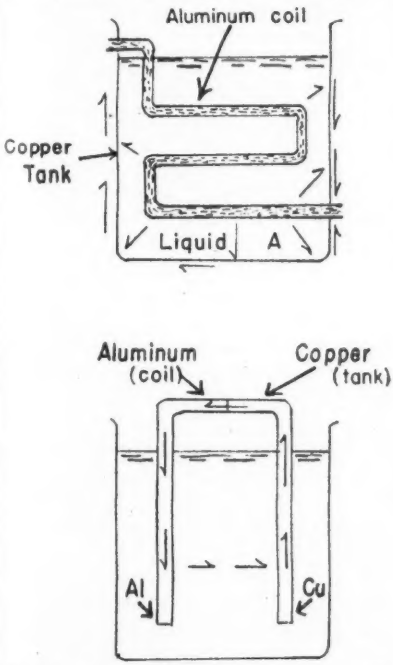


Figure 1 — Simple galvanic cell which should be avoided in the design of equipment. Single-headed arrows indicate direction of current flow.

Guide to Galvanic Action

The best simple guide to probable galvanic action is to measure the potential of the metal or alloy under the conditions of service. This usually allows one to determine which metal or alloy will be the anode and which the cathode under actual conditions, but gives little indication of the severity of the galvanic action. The current which flows between these metals must be measured in order to get reasonably accurate data on this point. The magnitude of the current depends on the relative areas of the dissimilar metals as well as other conditions. The current density at the anode determines the corrosion rate. Lower anode current densities and consequently lower rates of galvanic corrosion are obtained when there is a large area of the anodic material and a small area of the cathodic material than when the reverse is true. Thus, for example, it is usually better practice to employ rivets of a cathodic metal or alloy in a

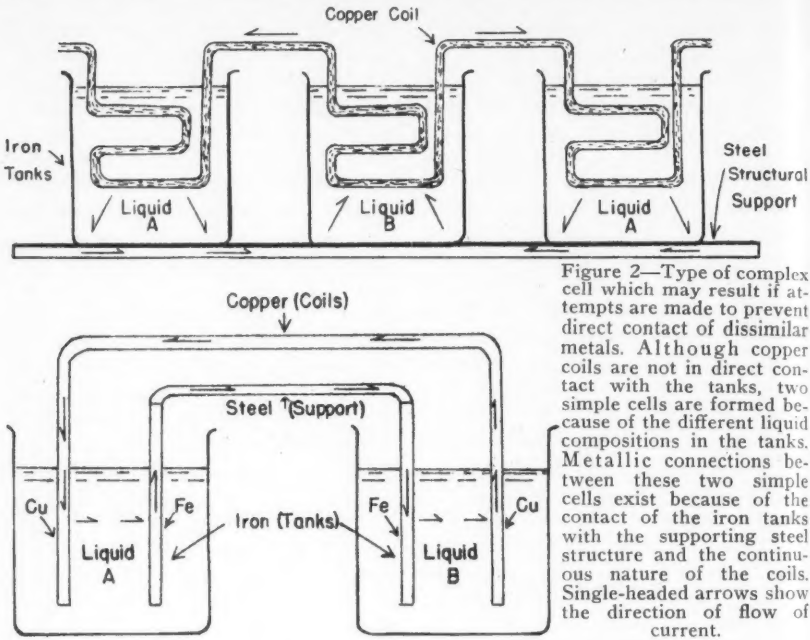


Figure 2—Type of complex cell which may result if attempts are made to prevent direct contact of dissimilar metals. Although copper coils are not in direct contact with the tanks, two simple cells are formed because of the different liquid compositions in the tanks. Metallic connections between these two simple cells exist because of the contact of the iron tanks with the supporting steel structure and the continuous nature of the coils. Single-headed arrows show the direction of flow of current.

plate of an anodic material than to reverse this relationship.

It is good design to avoid using dissimilar metals in contact with each other. Where dissimilar metals must be used, special precautions should be taken to prevent or alleviate galvanic corrosion.

In certain cases, where care is taken to avoid simple concentration cells or dissimilar metal cells, complex cells may still result which cause appreciable attack. There are many types of complex cells. However, a general idea of them can be obtained from a few examples.

One example is illustrated in Figure 2. In this case, two adjacent steel vessels are in electrical contact with each other through the supporting structure. In each tank there is a copper cooling coil insulated from the tank, but in electrical contact with other such coils. As long as liquids with the same composition, concentration and temperature are employed in both vessels, there will be no complex cell action. However, as soon as the liquids in the two vessels differ in some respect, corrosion can result from complex cell action. In the lower part of Figure 2 is shown a schematic diagram of a complex cell which may be used in the laboratory to study the effects produced in the above assembly.

Another example is shown in Figure 3. In this case, even when the solutions in the two vessels are identical and even though the cooling coils are insulated from the tanks, complex cell action may occur. In the lower part of Figure 3 is shown

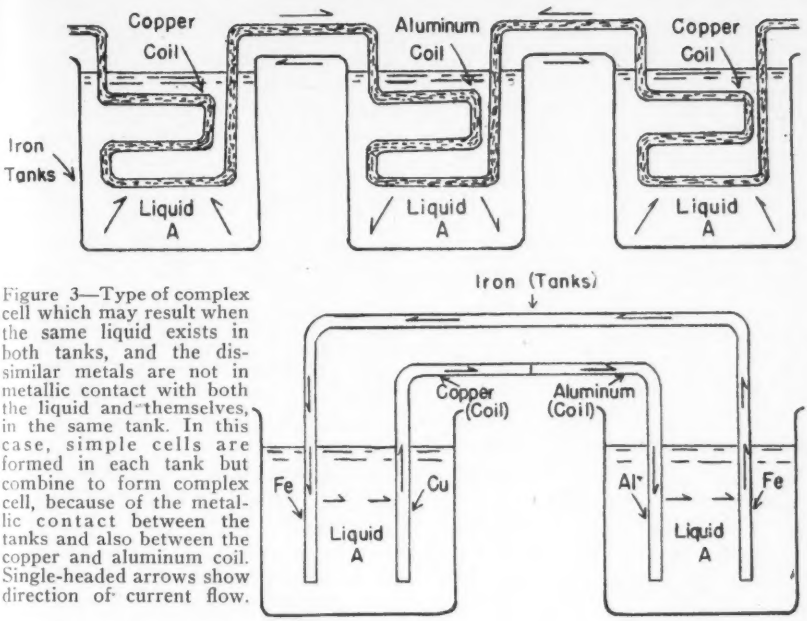


Figure 3—Type of complex cell which may result when the same liquid exists in both tanks, and the dissimilar metals are not in metallic contact with both the liquid and themselves, in the same tank. In this case, simple cells are formed in each tank but combine to form complex cell, because of the metallic contact between the tanks and also between the copper and aluminum coil. Single-headed arrows show direction of current flow.

a schematic diagram of a complex cell which may be used in the laboratory to study the effects produced in the above assembly.

It is readily apparent that if dissimilar metals are employed in almost any type of complex equipment or structure exposed to moist conditions, complex cell action may occur, even though the dissimilar metals are insulated from each other. For this reason, it is fortunate that galvanic corrosion resulting from complex cells is generally less severe than that resulting from direct contact between the dissimilar metals.

Even though dissimilar metals in the same piece of equipment are completely insulated and complex cells do not result, the presence of the dissimilar metals in the equipment may be the cause of another corrosion hazard. Such an example is shown in Figure 4. In this case the aluminum tank is not in contact with the copper coil. If the solution in the tank is sufficiently corrosive to cause even slight corrosion of the copper, copper compounds will be present in the solution. Copper ions from these corrosion products then can migrate through the solution and come in contact with the aluminum tank. As a result the copper ions will be reduced, plated out as metallic copper on the aluminum, and replaced in the solution by aluminum ions and corrosion products. Since metallic copper is now in direct metallic contact with aluminum, small local electrolytic cells are formed on the surface of the tank, and the corrosion of the alumi-

num is greatly accelerated. In the lower part of Figure 4 is shown a simple experimental set-up which may be used in the laboratory to study the effects produced in the assembly described above. In Table I are some data employing this type of simple laboratory test to study the effects of dissimilar metals in an assembly. The metals shown were aluminum and copper and the solutions were either sodium chloride or ammonium chloride.

It can be seen from these data that in most cases coupling aluminum to copper causes more acceleration of the corrosion of aluminum when in metallic contact with the copper than when insulated from the copper. However, in the case of ammonium chloride the corrosion is more severe when the aluminum is not in direct metallic contact with the copper. Evidently the corrosion caused by the ammonium chloride on the copper produced sufficient copper ions to accelerate the corrosion of aluminum to a greater extent than when the aluminum was in metallic contact with the copper and hence prevented the formation of copper corrosion products.

A similar result may be obtained, even though a copper coil is not used, if the liquid contacting the surface of the aluminum contains dissolved copper salts from any source whatsoever. Even in atmospheric exposures where an electrolyte may not be continuously present, corrosion products of a cathodic metal may be washed onto the surface of a more anodic metal, be reduced, form local electrolytic cells, and thereby accelerate corrosion.

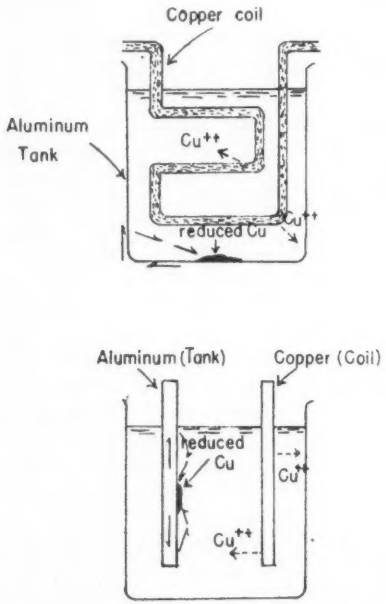


Figure 4—Example of acceleration of corrosion resulting from the pick-up of corrosion products from one metal, which accelerates the corrosion of another metal when the two metals are used in the same environment but not in direct or indirect metallic contact.

Methods of Alleviating Galvanic Corrosion

The most obvious method of eliminating galvanic corrosion hazards is to use one metal or alloy for the entire construction. This is not always feasible. In cases where it is impractical to do this, then consideration should be given to selecting combinations of metals or alloys which are known to develop little galvanic action under the service conditions. Alternatively, the dissimilar metals or alloys can be completely insulated electrically from each other. This will prevent direct galvanic effects but may not avoid

TABLE 1
Effect of Dissimilar Metals on Corrosion

	WEIGHT LOSS PER SPECIMEN—MGS.[1]			
	0.65N NaCl		0.65 N NH_4Cl	
	Aluminum	Copper	Aluminum	Copper
Al coupled to Cu in same beaker	35.5	9.6	37.3	3.2
Al and Cu in same beaker but not coupled	10.8	27.9	58.7	159.9
Two Al specimens in same beaker	2.5	.....	13.0	.....
Two Cu specimens in same beaker	.....	30.2	.....	398.5

Note: [1] Immersed area of specimens 1″ x 2″. Specimens exposed for seven days in 1000 cc of solution.

indirect effects, such as are discussed in the next section.

In some cases, the main undesirable effects of galvanic action can be prevented by the application of suitable paint coats to the contacting metal surfaces. It should be pointed out though that painting the anodic metal alone is usually not good practice. This simply reduces the anode area and allows intense galvanic action to occur at any breaks or discontinuities in the paint film. Instead, the surfaces of the cathodic member of the couple should certainly be painted, and it is also usually desirable to paint the surfaces of the anodic material as well.[6]

Sprayed metallic, hot dipped or electroplated coatings can also be used successfully in preventing undesirable galvanic action in certain cases. The surfaces of the cathodic metal, and sometimes the anodic metal as well, are coated with a metallic layer of a third metal which has a solution potential under the conditions of service equal to or higher than that of the more anodic metal in the couple.

Alternatively, strips of a metal or alloy which are anodic to the more anodic member of the galvanic couple can be attached in good electrical contact with one of the members of the couple near their point of contact. These strips of the third metal, if selected and attached properly, will cathodically protect both members of the couple. The attachments are themselves corroded and must be replaced periodically.

Corrosion by Contact with Nonmetallic Materials

Contact with nonmetallic materials frequently causes very severe attack of metals. Some nonmetallic materials, for example paper or cloth impregnated with flameproof compounds, contain soluble constituents which form highly corrosive solutions in the presence of moisture. More commonly, the nonmetallic materials do not contain specific corrosive agents. When they become wet, materials such as hairfelt, cloth, paper, and many insulating materials dry out slowly. Thus, a pad of a nonmetallic inert material may hold moisture in contact with the metal surface for prolonged periods of time without drying out. If such a pad is not present, freely circulating air could dry a wet metal surface and thereby reduce the corrosion hazard. In addition, the wet pad of nonmetallic material is ideal for causing oxygen concentration cells. The electric currents generated by these cells cause rapid corrosion

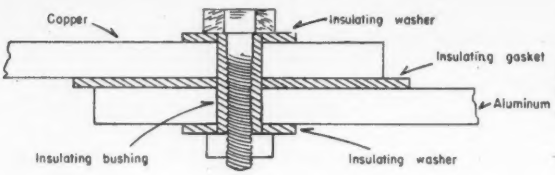


Figure 5—Method of completely insulating a joint composed of dissimilar metals.

of the anodic or screened areas of the metal surface.

This type of corrosion can be prevented by selecting nonmetallic materials known to be relatively innocuous, or by designing the equipment so that the nonmetallic materials are not likely to become wet or will dry out rapidly if they do. Painting the metal surfaces which will contact such nonmetallic materials is also desirable. Frequently the use of heavy protective coatings of suitable adhesives to attach the nonmetallic material to the metal surface is desirable. Also, in some cases, the nonmetallic material may be impregnated with a suitable corrosion inhibitor so that if it becomes wet, corrosion will be inhibited.

Corrosion Resulting from Moisture Pockets

In designing equipment which will be used in contact with water or aqueous solutions, it is good practice to eliminate pockets, low spots, or crevices where water will be trapped for extended periods of time. Usually, dry metal surfaces do not corrode; and the longer the total period of time that the surfaces remain wet, the greater the danger of corrosion. In addition, oxygen screening attack is likely to occur in wet areas which are screened from free access of air. For this reason, tanks should be designed to drain completely without trapping water in low areas. Butt welded joints are generally superior in resistance to corrosion to lap welded joints, since it is difficult to prevent the trapping of moisture between the faying surfaces of lap joints. In this case, lap joints have the further disadvantage that it is practically impossible to remove welding flux from the faying surfaces. Therefore, moisture lodging in these areas often becomes highly corrosive by dissolving some of the trapped flux.

Joints

Joints are likely to be particularly susceptible to corrosion. Therefore, design of joints usually requires special attention. If the joints are between dissimilar metals, means of preventing or alleviating galvanic corrosion should be considered. One method of alleviation is to insulate electrically the two materials from each other. Frequently this is not simple in the case of structures or equipment exposed in contact with liquids. If bolted joints are used, in order to obtain complete insulation, insulating bushings as well as insulating washers and gaskets are required. Figure 5 illustrates a means of completely insulating bolted joints of dissimilar metals. In most cases such a design cannot be used for riveted joints.

Another way of protecting joints

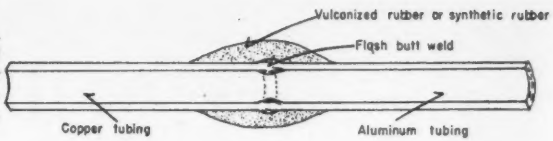


Figure 6—Method of insulating a joint composed of dissimilar metals under conditions where condensation of moisture will occur.

between dissimilar metals is to paint all surfaces of both metals in the vicinity of the contact area before assembly, and to caulk the joint with a suitable plastic sealing compound prior to assembling the joint. It is not satisfactory to paint surfaces of the anodic material only, since then attack will be localized at any discontinuities in the paint coating.

In the special case where it is desired to join tubes of two dissimilar metals, sometimes butt welding can be used. If a non-corrosive gas or liquid, such as a dry refrigerant, is being handled inside the tubes, no protection is needed at the joint in this area. The external surfaces at the joint can be protected from galvanic action from condensed moisture by coating them with a rubber sheath. One of the best methods of accomplishing this is to vulcanize the rubber right in place. A sketch illustrating this method of protection is shown in Figure 6.

Plating to Reduce Reaction

In certain cases, all areas of a dissimilar metal known to be cathodic to the other metal to which it is to be joined can be plated with a coating of a metal known to have the same potential as the anodic metal. For instance, copper or brass parts which are to be used in contact with aluminum parts can be cadmium-plated as a means of reducing galvanic corrosion. Cadmium is very similar in potential in many neutral solutions to aluminum. Therefore, as long as the cadmium coating remains on the copper base part, little or no galvanic attack of the aluminum will occur. Of course, once the cadmium coating is corroded away, then galvanic attack of the aluminum will occur. For this reason, this method of protection is generally only of temporary value.

Large Anodic Area Required

In designing joints of dissimilar metals, wherever possible, it is desirable to use as small a surface area of the cathodic metal and as large an area of the anodic metal as possible. This will reduce the intensity of attack on the anodic metal. Thus, it is better practice to use copper rivets in steel plate rather than steel rivets in copper plate. Furthermore, since the anodic metal is likely to suffer galvanic attack, it is desirable to keep the section thickness of the anodic metal as great as possible to allow for some corrosion loss.

Sometimes a sacrificial piece of a third metal or alloy can be added to the structure adjacent to the joint between the dissimilar metals in order to protect the anodic structural material from corroding. This form of protection is called cathodic protection.[7] Thus, if steel rivets are used in an aluminum structure, washers of zinc attached to the aluminum around the rivet heads will prevent selective corrosion of the aluminum under many conditions of exposure in liquid media.

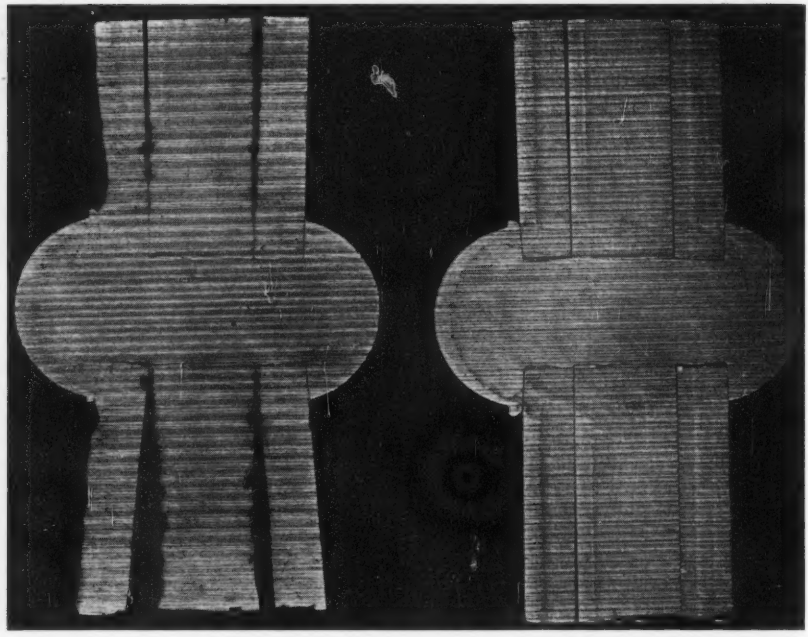


Figure 7—Example of crevice corrosion and a simple method of its prevention. Specimen on left shows a cross section through a joint composed of 17S-T plates and a 17S-T rivet, which was exposed to a marine atmosphere for eight years. Corrosion of the surfaces in the crevice has occurred because moisture could be held for long periods of time by capillary action. The corrosion product having a greater volume than the original metal has built up in the joint, causing it to spread. A similar joint is shown on the right, where one coat of aluminum paint was applied to the surface before the joint was assembled. Note that this simple precaution has effectively sealed the surfaces in the crevice and has entirely prevented corrosion for the same period of exposure.

The zinc washers will themselves suffer galvanic attack and will, therefore, require periodic replacement.

Joints Made Entirely of the Same Metal or Alloy

Joints are often especially susceptible to corrosion even when both members of the assembly are of the same metal or alloy. In the case of bolted or riveted joints, there are fine crevices between the faying surfaces and between the shank of the rivet or bolt and the hole walls. If liquids can penetrate into these crevices, oxygen concentration cells may be set up which result in special attack of the sheltered areas. For this reason, even where it is not necessary to use any special protection on the freely exposed areas of the metal surface, it may be necessary to protect the joints. The simplest protection is to prime the joint surfaces before assembly with a suitable primer. This should be allowed to dry before the joints are assembled. For many of the milder service

conditions, including exposure to outdoor atmospheres, this is frequently sufficient protection (Figure 7). In more severe locations, it is desirable to use a plastic caulking compound, such as Alumilastic, between the primed surfaces. Not all joint sealing compounds are satisfactory for this purpose. The best compounds are those which are initially soft enough to conform closely to the metal surfaces and which will maintain this property for extended periods of time. The compounds should not absorb water, they should not contain any constituents which will corrode the metal surfaces; and in some cases it is desirable that they contain a suitable corrosion inhibitor.

Elastic Materials Satisfactory for Caulking

While compounds which are initially plastic and which remain plastic are usually the most desirable, elastic materials such as rubber are also satisfactory, especially if they are cemented to the metal surfaces. The cement eliminates small crevices between the joint sealing material and the metal. If the crevices do not remain permanently cemented to the metal surface, or if the elastic material is water absorbent, crevices produced by the failure of the cement may be as bad in promoting corrosion as (or worse than) the crevices existing between metal to metal surfaces.

Use can also be made of cathodic protection to prevent joint corrosion. In solutions of high electrical conductivity, strips of some definitely anodic material attached to the metal surface in the vicinity of the joint will send sufficient current to the faying surfaces of a riveted or bolted joint to prevent corrosion at these areas. In this case it was found that zinc strips riveted on either side of a riveted 53S joint would prevent crevice corrosion in sea water even when the faying surfaces of the joint were four inches wide. Protection would not extend over as wide an area if the conductivity of the solution were significantly poorer than that of sea water.

A more positive method of preventing serious crevice corrosion is to coat the surfaces of the metal at and adjacent to the joint with a coating of an anodic metal. This can be accomplished by metal spraying, electroplating, hot dipping, or metal cladding (i.e., use of materials such as the alclad aluminum alloys). A result similar to that obtained by coating can be obtained by using a gasket of an anodic metal in the joint. This has the disadvantage that corrosion of the anodic metal may either loosen the joint or cause buckling of the joint plates as a result of accumulation of corrosion products from the anodic metal gasket.

Cathodic Protection

It was mentioned earlier that the areas of a metal surface to which current flows from the solution, the cathodes, frequently do not corrode. It is only the areas from which current leaves the metal to the solution which suffer attack. Thus, if the distribution of current is such that all areas of the metal surface receive current from the solution, usually little or no corrosion will occur. Protection by means of supplying current to the metal surface is called cathodic protection. The theory of this method of protection has been

discussed in several recent publications.[8,9]

The electric current required to give cathodic protection can be supplied either from an external source, such as batteries or generators, or it can be produced by galvanic action between the article being protected and an anodic metal anode. As long as an appropriate current density is maintained, it makes no difference which type of source is used. However, in general, cathodic protection is only feasible where the corrosion is caused by an electrolytically conducting liquid. That is, cathodic protection is generally of little value in retarding gaseous corrosion.

Cathodic Protection Used in Many Fields

Cathodic protection is used successfully for protecting steel pipe lines,[10] steel water storage tanks,[11] steel hot water tanks,[12] the steel hulls of marine vessels,[13] aluminum chemical equipment,[14] and aluminum marine equipment.[15] In the special case where the anodic material is applied as a coating, cathodic protection is also effective in protecting steel sheet from atmospheric corrosion (galvanized steel) and from the action of food products (tinned steel food containers). Cathodic protection is also effective in rendering the alclad aluminum alloys extremely resistant to outdoor exposure.[16] The use of coatings which give cathodic protection will be discussed in more detail subsequently.

If current from an external source is used to give cathodic protection, the open-circuit potential of the anodes is not of great importance. Of more importance is the use of either non-corrodible anodes or anodes of low cost, either type of which must not polarize sufficiently to reduce greatly their current carrying capacity. Anodes of graphite, carbon, iron, steel, or aluminum have all been used commercially. Each has its own characteristic advantages and disadvantages. Graphite or carbon anodes are relatively expensive and have undesirable mechanical properties, especially low strength and brittleness, which make them inconvenient to use. Anodes of cast iron or steel probably have been used more than any others. Often scrap metal is used for anodes, thus making their cost very low. Recently aluminum anodes have been used to some extent.[17,18]

TABLE II

Electrochemical Equivalents of Several Metals

METAL	Ampere Hours per Pounds of Metal
Magnesium	997
Aluminum	1352
Zinc	372

Advantages of Aluminum

Advantages of aluminum are its light weight, making transportation and installation of the anodes easier, and its low electrochemical equivalent, which means that a smaller weight of aluminum is attacked for each unit quantity of current passed than is the case for any other common metal. The weights of various metals consumed by one ampere year of current (at 100 percent current efficiency) are given in Table II.

Typical installations of cathodic protection where current from an external source is supplied are illus-

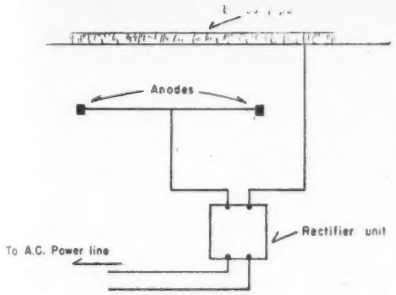


Figure 8—Cathodic protection of a buried pipeline, using current from an external power source.

trated schematically in Figures 8 and 9.

In cases where current is supplied by galvanic action between the anodes and the article being protected, the relative solution potentials of the anodes and of the metal to be protected, when measured under the conditions of exposure, are of prime importance. Obviously, the potential of the anode must be appreciably higher than that of the material being protected, or else there will not be sufficient current passed to prevent corrosion. It is also important that the anode material remain unpolarized under the conditions of service; otherwise the current supplied by the anode may in time be reduced to a value so low that protection will not be obtained.

In the past, zinc anodes have been the galvanic anodes which were used the most widely for protecting steel (or aluminum) structures. At the present time, magnesium and aluminum alloy anodes are also being used. These light metals have higher solution potentials than zinc when they are installed correctly and so provide more current per anode. They also both have lower electrochemical equivalents than zinc, which means that, theoretically at least, they will provide more ampere hours per pound of metal attacked than will zinc. Examples of using galvanic anodes to protect cathodically structures or equipment are illustrated schematically in Figures 10 and 11.

For cathodically protecting amphoteric metals, such as lead and alumium, galvanic anodes have the special advantage that excessive currents are more easily avoided. Excessively high currents flowing to cathodes of amphoteric metals can cause a special form of corrosion termed cathodic corrosion. Excessively high currents flowing to ferrous metal cathodes have never been observed to cause corrosion of this type.

Galvanic anodes have additional

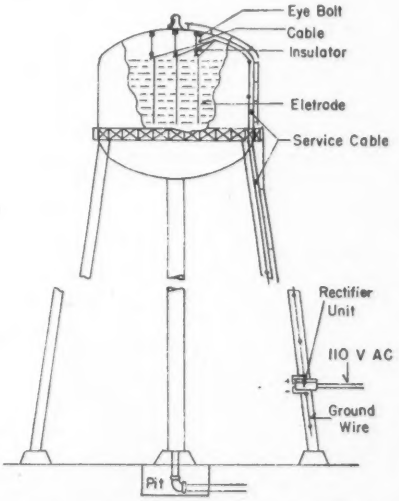


Figure 9—Cathodic protection of the interior of a water tank, using current from an extrenal power source.

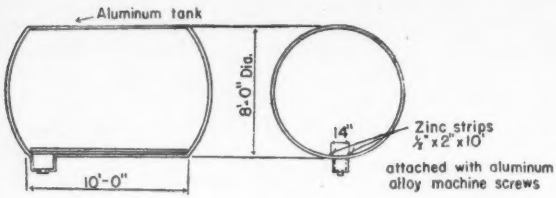


Figure 10—Method of attaching zinc strips to protect cathodically the interior of an aluminum tank.

advantages in that they are easier to install and do not require as much maintenance as when current from an outside source is applied. Galvanic anodes must be replaced periodically, since they are consumed in supplying the current. However, generally when they are used in properly installed systems, they will continue to give protection for a period of several years at least.

Mention was made earlier that certain metallic coatings gave cathodic protection to the basic metal under many conditions of service. The most familiar example of this is obtained with galvanized steel. With this material, the zinc coating not only mechanically screens the steel core from contact with corrosive agents but also will protect the steel core from corrosion in many environments at sheared edges, scratches, or other regions where the coating is not continuous. This protection at such areas is cathodic protection, and will only be obtained in exposure where the zinc coating is definitely anodic to the steel core, and where there is a continuous conducting path of solution or moisture between the bared area and the adjacent coating.

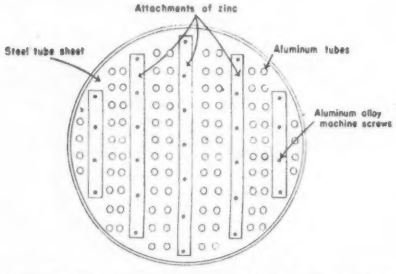


Figure 11—An example of the use of zinc anodes to protect aluminum tubing from galvanic attack resulting from the contact with a steel tube sheet.

The alclad alloys of aluminum form the next most common example of the use of coatings which cathodically protect the core material. In the case of the alclad alloys, the coating is applied mechanically during fabrication of the material. Subsequently the duplex alloy is subjected to both heat and pressure, so that the coating becomes bonded metallurgically to the core. The composition of the coating is selected so that it will be anodic to the core material under most conditions of service. Where the core material is a duralumin type alloy, a pure aluminum coating is employed, since pure aluminum is definitely anodic to the duralumin alloys. The remarkable resistance to perforation under very corrosive conditions was exemplified in the following test. The corrosive conditions were severe, as shown by the fact that a container made of 0.040-inch thick 3S was perforated after 480 hours' contact with boiling water, which contained appreciable amounts of heavy metals such as copper. However, a similar container

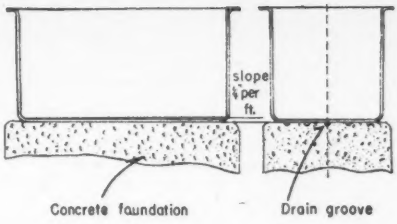


Figure 12—A satisfactory method of supporting a flat-bottomed aluminum vessel. By means of the slight slope and by providing drain grooves in the concrete, the corrosive liquid may be drained away.

made of Alclad 3S, although showing corrosion of the alloy coating, had not perforated after 1550 hours' contact with the same boiling water. The test was discontinued at this time, because it was evident that the attack penetrated only through the coating to the core alloy and then spread out, showing that the coating alloy was electrochemically protecting the 3S base. The alclad alloys are extremely resistant to structurally serious attack in most natural environments.

Metallic Coatings Must Be Selected With Care

Coatings of metals or alloys which are cathodic to the basic material behave in just the reverse manner and will accelerate attack of the basic metal unless the coatings are absolutely continuous. Under many conditions of exposure, the coating on tinned steel will accelerate the attack of the steel core at any points where it is exposed. However, when exposed to certain fruit juices, as in the case of food containers, the tin coating becomes anodic to the steel core[19] and so gives the core cathodic protection.

It is often good design practice to take advantage of cathodic protection, either by using external anodes or metallic coatings which are anodic. This is particularly true if the exposure conditions are definitely corrosive and if other means of protection are not feasible.

Corrosion is usually more likely to occur at inaccessible areas, where dirt or other moist solids can accumulate, than on freely exposed surfaces which are kept clean by use or by periodic cleaning treatments. It is an old saying that "Busy metal does not corrode." This is true under many service conditions. Therefore, it is good design to avoid crevices or to use special protection at joints, pockets, or other inaccessible

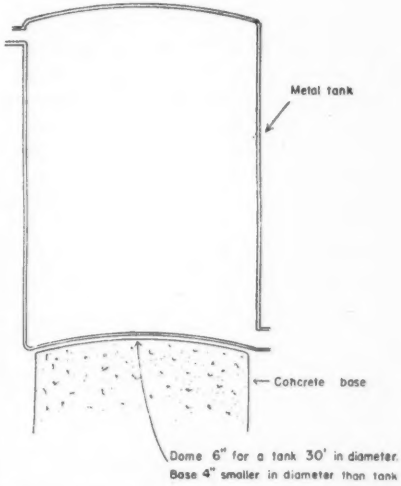


Figure 13—By providing a domed support (exaggerated in the drawing) the corrosive liquids may be drained away.

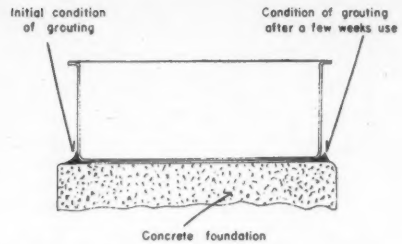
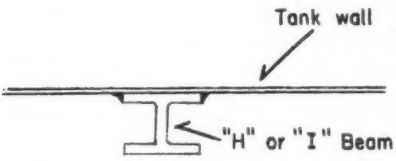


Figure 14—Improper method of supporting a flat-bottomed vessel.

areas. Where complete sealing is not feasible or where a piece of equipment is used intermittently, it is always advisable when possible to provide ventilation so as to have free air circulation in order to evaporate moisture as rapidly as possible, and also to prevent the formation of additional moisture by temperature changes which would produce a condensate. In cases where cleaning is feasible, the design should be such as to permit periodic clean-



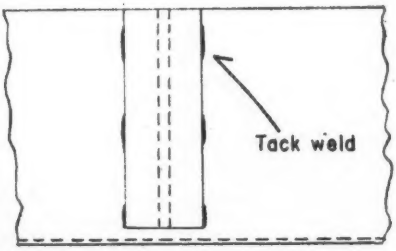


Figure 16—A satisfactory method for stiffening a flat wall vessel employing an I-beam.

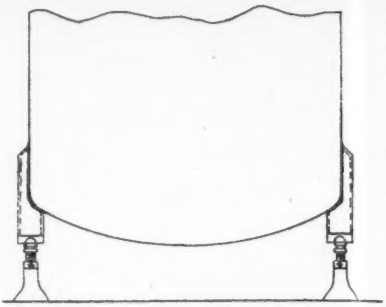


Figure 15—An improved method for supporting round-bottomed tanks.

ing. A few examples to illustrate these points will be given.

In supporting large flat-bottomed tanks in chemical or food processing plants, it is better practice to design so that free air circulation to the exterior surfaces is permitted than to seal off incompletely the bottom surfaces, thus permitting accumulation of moisture and dirt in this area. Methods of supporting tanks of this type which have given good results in service are illustrated in Figures 12 and 13. A method support which has proved very unsatisfactory is illustrated in Figure 14.

From the standpoint of avoiding corrosion, it has proved much simpler to design supports for round-bottomed tanks. Typical satisfactory method is illustrated in Figure 15.

The design of stiffeners and other side supports for large tanks or vats which will be used in wet locations is also of importance if corrosion is to be avoided. The first consideration is to use designs which will give the least chance for moisture entrapment and the greatest chance for air circulation. Satisfactory designs are shown in Figures 16 and 17. An unsatisfactory design is illustrated in Figure 18.

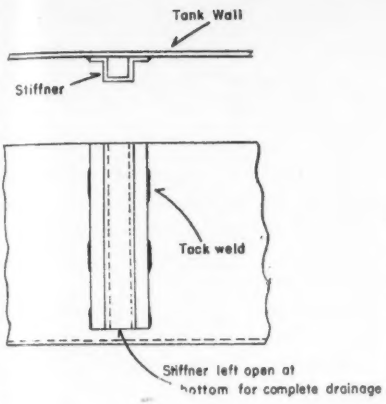


Figure 17—A satisfactory method for stiffening a flat wall vessel employing a hat section. In order to insure drainage and free air circulation, the top and bottom of the hat section should not be closed.

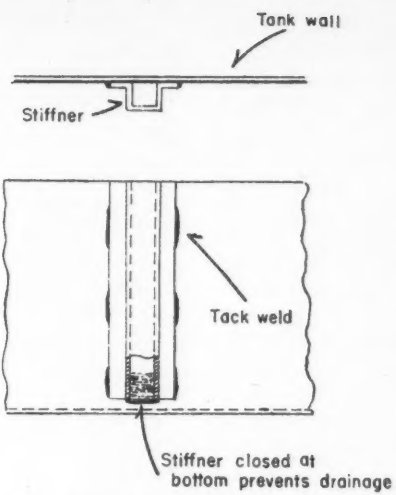


Figure 18—Unsatisfactory non-draining stiffener for a metal vessel. Note that closing the bottom permits the collection of liquid and prevents free air circulation.

In the design of equipment employing either formed or rolled shapes such as channels, I-beams, H-beams, et cetera, it is well to consider the effect of the shape of the member and its position with regards to the entrapment of water. In Figure 19 are shown three ways in which a channel might be installed. Obviously the first example with the legs of the channel vertically upwards is poor design from a corrosion viewpoint. If it is necessary to install a panel in such a position, it is well to provide drain holes as shown in the second sketch of Figure 19. A much preferred design would be to turn the legs of the panel vertically downward, thus preventing the entrapment of water entirely.

In the case of tanks and other items of chemical equipment, it is desirable that they be designed to drain completely. Frequently the liquid being stored in the vessels is not in itself corrosive. However, if this liquid is drained off incom-

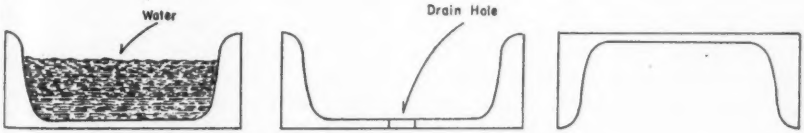


Figure 19—Proper and improper methods of installing channels. Left shows poor design, in that water is allowed to collect. By providing a drain hole as shown in center example, moisture can be drained off. However, by inverting the channel as shown at right, the collection of moisture is completely prevented.

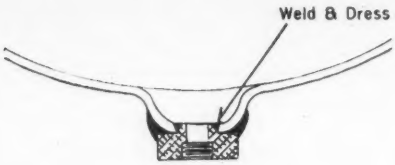


Figure 20—An example of correct drain design which allows complete drainage.

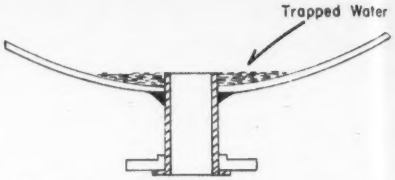


Figure 21—an example of improper drain design which allows trapping of moisture.

pletely, leaving pools on the bottom of the vessel, it will become corrosive in time, either as a result of concentration by evaporation, pollution from the surrounding air, or fermentation and decay. For this reason, the bottoms of flat-bottomed tanks should have a definite slope to the drain, and the drain itself should be the lowest point in the tank. Correct and incorrect drain designs are shown in Figures 20 and 21.

Proper Drain Facilitates Cleaning

Equipment of the type which drains completely has the further advantage that periodic cleaning is facilitated. Periodic cleaning is often very effective in prolonging useful life. For example, as a laboratory test a corrosive water was boiled for eight hours a day in two identical aluminum pans. One pan was rinsed out twice a day, while the other was cleaned thoroughly with steel wool and soap twice a day. The pan which was only rinsed became perforated by corrosion after 300 hours' boiling, while the cleaned pan was still in excellent condition after 1000 hours. Appropriate methods of chemical cleaning proved as effective as steel wool and soap. Periodic cleaning is not always a feasible method of prolonging useful life. However, it can be used in some cases very satisfactorily. In designing equipment, consideration should be given to making periodic cleaning easy to accomplish. By designing so as to avoid sharp corners and by the introduction of fillets of relatively large radius, cleaning can be accomplished with greater ease.

It is, of course, desirable to design equipment so that it will remain serviceable indefinitely without any necessity for repairs required by corrosion. However, it is not always possible to do this. Therefore, it is good design practice to construct equipment so that parts which fail by corrosion can be readily replaced. One commonplace example will illustrate this general idea.

Removable Condenser Tubes

Condensers for chemical plants are commonly made with heavy shells and headers. The condenser tubes generally have relatively thin walls in order to conserve space. Consequently, failure of condenser tubes by corrosion is much more likely to occur than is failure of the shells or headers. For this reason, frequently one of the two tube sheets in the condenser is designed to be of the "floating" type, so that when failure of the tubes occurs, the entire tube bundle can be removed easily and the corroded tubes replaced with new tubes in a repair shop without prolonged shutdown of equipment.

Designing for ease in repairing

corrosion damage is always important when it is impractical to design to prevent corrosion.

Corrosion inhibitors can frequently be employed economically in closed systems, for treating recirculated waters or brines, or in tanks where there is no continuous flow. It is generally uneconomical to use corrosion inhibitors in liquids which only pass through the system once and are then consumed or wasted.

Chromates Effective Inhibitors

The chromates are the most effective inhibitors in common use. A small amount of a soluble chromate, when added to a corrosive water, will often greatly reduce the total amount of metal attacked by this water. Under suitable conditions, the chromate addition may virtually prevent any further attack from occurring. Chromates are most effective when the water being treated is low in chlorides, not at a very elevated temperature, and when galvanic or electrolytic corrosion is absent. If chromates are used in too low concentration, at too elevated temperatures, or when galvanic or electrolytic effects are present, they may only give partial protection. Under such conditions, a highly localized but very penetrating type of corrosion may result. For this reason, considerable information is required in order to determine whether the use of chromate inhibitors is justified in any specific case.

Silicates are frequently used as corrosion inhibitors. Generally they are not as effective as the chromates, but may be more suitable for use in certain instances because there is less risk of intensified local attack occurring.

Soluble oils are also sometimes used as corrosion inhibitors. In the case of aluminum, at least, they are often the safest of the inhibitors, although not the most effective.

Since galvanic effects are likely to break down inhibitor action, it is desirable to avoid the use of dissimilar metals in systems which will handle inhibited water or solutions. Furthermore, some chemicals will inhibit corrosion of one metal and stimulate corrosion of another. If it is known that a certain inhibitor will be used in a given medium, particular attention should be taken to avoid including parts made of some material which is adversely affected by the inhibitor in the system. Also, the system should be designed to permit the ready addition of the inhibitor and the taking of liquid samples to check the inhibitor concentration.

Aqueous Fluids Problem

Inhibitors can sometimes be used in large tanks or vessels where the liquid being processed is not itself corrosive, but where a separate, often aqueous, phase which is corrosive is also present. In an aircraft gasoline tank, for instance, the gasoline itself is not corrosive, but condensed or entrapped water which accumulates in the bottom of the tank may be strongly corrosive. Attack by this aqueous layer can be prevented by providing a capsule filled with a water soluble inhibitor in the bottom of the tank so that any water which accumulates there will dissolve sufficient inhibitor to render it non-corrosive. In such a case, care must be taken to install the capsule in the lowest spot in the tank and

to design the tank so that any water which settles out will flow to the capsule and thus contact the inhibitor. As has been pointed out in previous sections, it is well to design such tanks with a sump. In the case of such designs, the capsule can be placed in the sump. It is also important that the material composing the capsule itself be galvanically inert with respect to the tank. Otherwise, galvanic attack resulting from contact between the tank and the capsule may be more severe than the corrosion which would have occurred if the inhibitor capsule had not been used.

In cases where an absorptive nonmetallic material, such as hairfelt, cork, paper, etc., will be in intimate contact with a metal surface in the presence of water, impregnation of the nonmetallic material with a suitable water soluble inhibitor may prevent serious corrosion. Sodium chromate is the inhibitor which is frequently used for this purpose. However, it has such a high solubility that a relatively small amount of water may leach practically all of the chromate out of the nonmetallic material. If, subsequent to this, additional moisture is introduced, insufficient chromate may remain to inhibit the new water. For this reason chromates with a lower solubility than sodium chromate are sometimes used. Generally these are precipitated in the nonmetallic material by a two-step treatment. Strontium chromate and zinc chromates are two of the sparingly soluble chromates which have been used for this purpose.

References

1. U. R. Evans and T. P. Hoar; Proc. Royal Soc. **A137,** 343, 1932.
2. R. H. Brown and R. B. Mears; Trans. Electrochem. Soc. **74,** 495, 1938.
3. R. S. Thornhill and U. R. Evans; J. Chem. Soc. 614, 1938, 2109, 1938.
4. R. B. Mears and R. H. Brown; Ind. & Eng. Chem. **33,** 1001, 1941.
5. D. W. Sawyer and R. B. Mears; Ind. & Eng. Chem. Analyt. Ed. **17, 2,** 1945.
6. R. H. Brown; ASTM Bulletin **126,** 21, 1941.
7. R. B. Mears and R. H. Brown; Trans. Soc. Nav. Arch. & Mar. Engs. **52,** 91, 1944.
8. R. B. Mears and R. H. Brown; Trans. Electrochem. Soc. **74,** 519, 1938.
9. R. H. Brown and R. B. Mears; Trans. Electrochem. Soc. **81,** 455, 1942.
10. W. T. Smith and T. C. Marshall; Gas Age, Aug. 17, 1939.
11. L. P. Sudrabin; Water Works and Sewerage, Feb., 1945.
12. L. P. Sudrabin; Water Works and Sewerage, May, 1945.
13. R. B. Mears and R. H. Brown; Trans. Soc. Nav. Arch. and Mar. Engs. **52,** 91, 1944.
14. R. B. Mears and H. J. Fahrney; Trans. Amer. Inst. Chem. Eng. **37,** 911, 1941.
15. H. D. McKinnon; Proc. Second Annual Water Conf., Eng. Soc., West, Pa., Page 15, 1941.
16. E. H. Dix, Jr., and R. B. Mears; Paper presented at ASTM meeting, Pittsburgh, Pa., Feb. 27, 1946, to be published in Proc. ASTM.
17. R. B. Mears and C. D. Brown; Corrosion **1,** 113, 1945.
18. L. P. Sudrabin and R. B. Mears; Proc. Amer. Inst. Elec. Engrs., 1946, in process of publication.
19. T. P. Hoar; Trans. Faraday Soc. 3, 480, 1934.

Discussion

By Dr. M. G. Fontana

Professor of Metallurgical Engineering, Ohio State University, Columbus, Ohio

This discussion does not particularly apply to the foregoing paper, but there are several remarks that interest me. First is the manner of presenting data, and means of expressing corrosion results. I should like to propose what I think is a good engineering term. For instance, if your data are in "MDD's," and you, as an engineer, look at them, you have to make mental calculations, or do some figuring, to translate these data into engineering terms. You, as an engineer, are interested primarily in life of equipment. We in the chemical industry usually figure on five years, or ten years at the most, whereas in designing buildings, you are probably interested in a hundred years. "Inches per month" is another rate used and the first thing you do is to multiply by twelve, and try to figure out how many years the equipment will last. "Percent weight loss," of course, does not mean much because the rate of corrosion is entirely different if the tests are made on thin sheet, as compared to a solid sphere. The results could be widely divergent in the same test. I think "inches per year" comes closest to the best engineering term, though we have some difficulty in presenting data. If the rate of corrosion is very low, you have a decimal point with a few zeroes, and so on. So, what I would like to propose is the expression of corrosion rates as "mils per year." This method has the advantage of being expressed in years, and it does away with decimal points and cumbersome figures and table listings, since in most cases you will have whole numbers. Fractions of mils would have little practical significance as far as predicting service life is concerned.

Corrosion ratings of metals may be some sort of a guide for the uninitiated but I think they are of little value to the corrosion engineer. In the first place such ratings usually have a long list of qualifications attached to them. Granted that most of the corrosion is more or less uniform where these ratings would apply, the unexpected or unpredictable types of corrosion are the ones that give us trouble. We are not too worried about uniform corrosion because in most cases a simple test will give you a pretty good indication of how long the equipment will last. So, I have always sort of depreciated the idea of putting out handbooks, or making corrosion a handbook proposition. We have carefully avoided trying to give the plants what we would call handbook information. In other words, you cannot turn to page so-and-so and solve your problem.

Most of the corrosion is uniform, but I think the other forms really present the problems. I have arbi-

trarily classified corrosion into the eight forms in which it manifests itself: (1) uniform corrosion; (2) pitting; (3) galvanic action; (4) concentration cell corrosion; (5) dezincification and similar phenomena; (6) intergranular attack; (7) stress corrosion; and then what happens to be one of my pets, (8) erosion-corrosion.

These are the points I wished to make—(a) good standard engineering term so that when we read the literature, the data are more or less comparative, and we do not have to do a lot of calculating to come up with the information we want; (b) that you should be very careful in using corrosion data in handbook form. Based on fifteen years' experience in corrosion work, I believe that solution of corrosion problems could be based on the following: Twenty-five percent data, 50 percent experience, and 25 percent just plain old fashioned horse sense.

Results of Some Studies of the Condensate Well Corrosion Problem*

By Walter F. Rogers and Harry E. Waldrip
Chemical Department, Gulf Oil Corporation, Houston, Texas

SINCE the presentation of the paper by Bacon and Brown[1] on the condensate well corrosion problem, considerable investigational work has been done on this subject of this latter work, Jessen[2] indicates that the corrosion of steel equipment in condensate wells is related to the rate of absorption of carbon dioxide from the gas to the aqueous film on the metal, and that the ratio of condensed water to condensate is of importance.

Rogers[3] has shown that waters from condensate wells develop low pH values of the order of 4.00 on aeration and standing from original values of 5.95 to 6.25. This development of low pH results from the oxidation and precipitation of ferrous salts in the ferric state leaving the acid radical in solution.

Menaul[4] has shown that aliphatic acids of the formic-valeric group are present in these condensate waters and are largely responsible for the low pH values obtained from the oxidation and precipitation of their iron salts. Studies have since been made on the corrosion rates of steel in propionic acids[5] and much work has been done on the analytical separation and identification of these aliphatic acids.[4, 6, 7]

Aside from the determination of these few factors which enter into this corrosion problem, little else is known that is separate and distinct from oil-well corrosion in general. The investigation of the role of the various specific factors which can enter into this corrosion problem is continuing, and eventually the controlling ones will be determined.

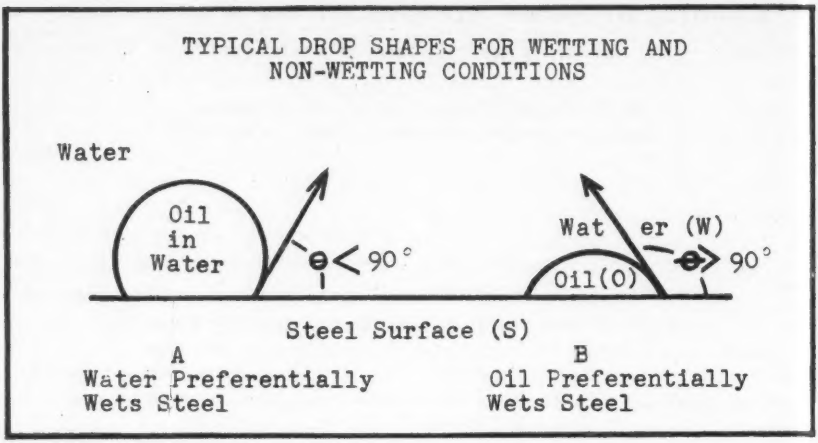
It is the purpose of this paper to present some data on the importance of a single angle of this problem; i.e., the ability of the liquid hydrocarbons produced by condensate wells to form protective films on metal well equipment. The data are extended to show the result of carrying the results of laboratory testing to the field.

Meaning of Wettability and Its Importance in Preventing Corrosion

It is a well recognized fact that many petroleum oils and greases are in themselves non-corrosive to steel, and their application to metals to prevent corrosion by aqueous films is of great industrial importance. Condensate fluids, on the other hand, are suspected of being of doubtful protective value. This results from the corrosion experience to date, from the handling of gasoline through pipelines as contrasted with the han-

★A paper presented at the NACE Conference in Kansas City, Mo., May 7-9, 1946.

FIGURE 1



dling of sweet crude oils. It is known that gasoline pipelines suffer rapidly from corrosion[8] unless special corrosion inhibitors are added. It is equally well known that sweet oils offer excellent protection to the lines through which they are pumped. Since condensate liquids are more nearly related to gasoline than crude oil, it would be suspected that they are not highly protective in nature.

It is further suspected that, the corrosion experienced in condensate wells is linked with a lack of wettability of the condensate for steel in the presence of the water produced, with the hydrocarbon liquid. The wettability of the hydrocarbon is the relative ability of this material to displace water from steel when the metal is in contact with both aqueous and hydrocarbon phases. Based on the assumption, therefore, that the condensate liquid itself is non-corrosive, it is desirable to produce a hydrocarbon liquid of such properties that it will displace the corrosive aqueous layer from the well metal surface.

Figure 1 shows the phase relations existing between oil and water on a steel surface. In Figure 1-A a droplet of oil has been placed on steel immersed in an aqueous fluid, and the oil droplet has developed a base against the steel. In the notation

S is the steel surface
O the oil
W the water
γ is the interfacial tension symbol.

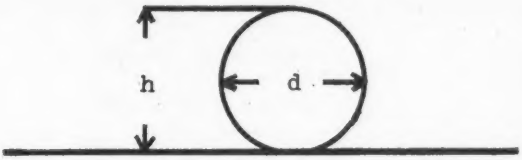
The relation between the interfacial tensions at equilibrium is expressed by the equation:

$$\gamma_{SO} = \gamma_{SW} + \gamma_{WO} \cos \theta$$

Where SO is the interfacial tension between the solid and oil, and the other subscripts have similar meanings. In the case of Figure 1-A, the angle θ is less than 90°. This means that the interfacial tension of the solid-oil surface is greater than the interfacial tension of the solid-water surface; and the water has the greater wetting power. As the interfacial tension of the oil-solid surface

FIGURE 2

DROP-SIZE RATIO MEASUREMENTS



SPHERE $h/\frac{1}{2}d = \frac{2r}{r} = 2.000$

HEMISPHERE $h/\frac{1}{2}d = \frac{r}{r} = 1.000$

FLAT LAYER $h/\frac{1}{2}d = \frac{0}{\infty} = \text{Zero}$

decreases as shown in Figure 1-B, the oil drop spreads and the angle θ tends to approach 180°. Under normal nomenclature, it is considered that preferential wetting does not occur for a liquid unless the angle θ for that liquid is less than 90°. In the figure as drawn, water wets the steel preferentially for angles of θ less than 90° and oil wets the steel preferentially for angles over 90°.

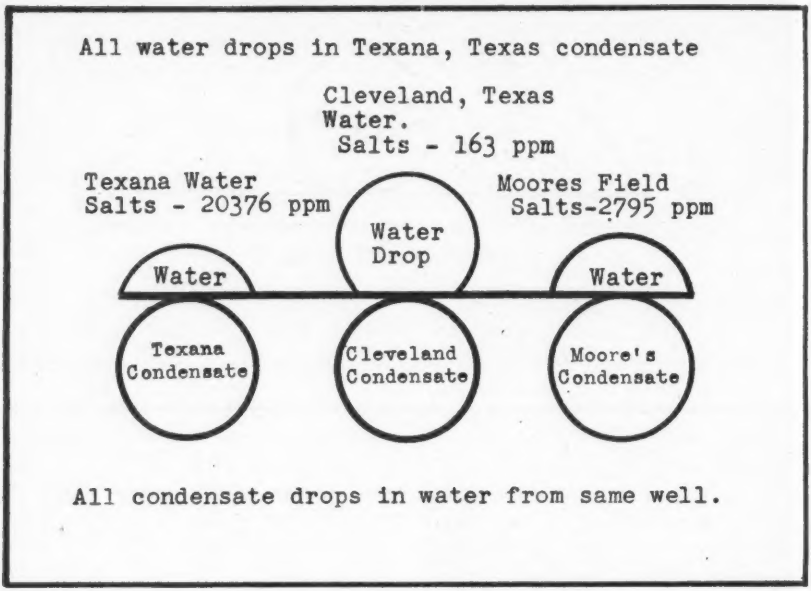
Apparatus and Procedure

The sessile drop method was used in this study of the relative wetting ability of the various condensate fluids for steel in the presence of the aqueous media produced with them. The apparatus consists of a 1½" x 2¼" x 2½" O.D., clear glass cell, with glass internal shoulders 1/16" wide extending the width of the cell and to a height of one inch above the bottom. This cell is held in place in a clear glass water bath by means of a metal basket suspended from the top of the bath. A pump circulates clear water around the test cell to keep the fluid at room temperature of 75° F. A fluorescent lamp mounted behind the cell furnishes light for viewing the sessile drop with a 15-power measuring microscope. When in use, the test cell is filled with the fluid in which the test is to be made.

A specially prepared sheet-steel specimen 2" x ⅞" of 20-gage thickness is used for the metal surface. The metal specimen is lowered into the liquid phase and allowed to rest on the glass shoulders of the cell in a horizontal position. The drops are placed by special pipettes. For use with condensate, these are made by softening five mm. O.D. soft glass tubing in a flame, making a full draw and bending the small diameter drawn tubing in a U turn. The glass is then broken just above the U turn. The diameter of the glass tubing at the fine end should be

FIGURE 3

WETTING OF STEEL BY WATERS AND CONDENSATES IN THE PRESENCE OF EACH OTHER



about 0.50 mm. The length of the bend should be such that it can be put under the steel specimen. The full diameter portion of the pipette is about four inches in length. A section of rubber hose long enough to reach from the large diameter portion of the pipette to the mouth is put in place. To load the pipette the small end is immersed in the condensate to be tested and some liquid pulled into it by suction. The outside of the end is then wiped free of condensate using clean cheesecloth. The pipette end is then placed in the fluid under the steel and tiny drops blown. These must not be over 0.10 cm in diameter and preferably not over 0.05 cm.[9] Each drop when blown is shaken from the pipette by gentle tapping, causing the droplets to rise to the steel face. Usually four such drops are placed in position. After the drops are placed, their size is measured immediately and then after three hours standing. It has been found that equilibrium is essentially reached by this time.

If water drops in condensate are to be studied instead of the reverse, the procedure is altered slightly because of the reversal in relationship of specific gravity of the two components. In this case, the prepared metal is placed on the cell shoulders face up and is covered with the condensate in which the tests are to be made. A straight pipette is filled

TABLE I

Analyses of Waters from Condensate Wells

	Moores Field, Texas	Cotton Valley, Louisiana	Cleveland, Texas	Krotz Springs, Louisiana	Hayes, Louisiana	Texana, Texas	Opelika Texas, Well A, 12-11-45
Producing Tubing Pres., psi	1140	1780	....	3000	4150	1100-2200	1900
Bottom Hole Temp., °F	220	272	220	197	210	168	240
Well Depth, Feet	7322	8327	9099	8483	11,670	5710	8500
pH at Well Head	5.75	....	5.75	....	4.50	6.50	....
pH as Received	4.03	6.30	5.30	5.97	....	5.75	5.25
Sodium, ppm	702	230	41	1853	1264	7760	45
Calcium, ppm	212	124	2	116	130	136	84
Magnesium, ppm	35	12	Nil	29	24	45	6
Bicarbonate, ppm	....	414	67	156	216	160	24
Chloride, ppm	1546	318	28	3050	2125	12,090	213
Sulfate, ppm	....	62	....	12	0	5	12
Iron, ppm	300	300	25	55	300	280	70
Total Solids, ppm	2795	1460	163	5271	4059	20,376	454
Iron Rerun, ppm	....	....	....	....	....	....	....
Daily Water, Bbl.	7	11	1	1.0	2	1.5	8.0
Daily Condensate, Bbl.	150	302	33	44	26	9.0	400
Corrosion Rate	Corrosive	Corrosive	Non-Corrosive	?	?	Moderately Corrosive	Corrosive

	OPELIKA, TEXAS		PALOMA, CALIFORNIA			
	Well A, 3-28-46	Well B, 3-28-46	Well A	Well B	Well C	Well D
Producing Tubing Pres., psi	1900	1900	3000	2250	2650	2350
Bottom Hole Temp., °F	240	240	251	246	250	245
Well Depth, Feet	8500	8500	10,288	10,833	10,803	10,844
pH at Well Head	.....	.....	5.35	6.03	6.70	5.90
pH as Received	4.86	4.75	4.50	3.90	7.40	3.88
Sodium ppm	242	4	1430	200	8120	314
Calcium, ppm	1156	53	84	16	124	16
Magnesium, ppm	33	3	20	7	29	8
Bicarbonate, ppm	12	6	.....	.....	1380	....
Chloride, ppm	2500	103	2410	354	12,000	530
Sulfate, ppm	40	4	7	....	43	7
Iron, ppm	50	36	....	60	4	....
Total Solids, ppm	4033	173	4116	637	21,700	1025
Iron Rerun, ppm	....	....	150	300	12	80
Daily Water, Bbl.	8.0	....	Trace	8	77	8
Daily Condensate, Bbl.	400	....	429	519	658	552
Corrosion Rate	Corrosive	Non-Corrosive	?	?	?	?

with the aqueous fluid. The pipette end is immersed in the condensate and a drop of the proper size blown. The pipette is then drawn up through the air-condensate surface, causing the aqueous drop to be sheared from the pipette, after which it falls through the condensate to the metal face. Four drops are so placed and are measured as described before.

The method of steel preparation has been found to be of extreme importance in obtaining duplicatible results; and a standard procedure has been developed which enables this to be obtained. The steel specimen of 1020 material is cut from a larger sheet. It is then ground and polished with various sized emery cloths until flat, followed by a polish with clean dry crocus cloth to give

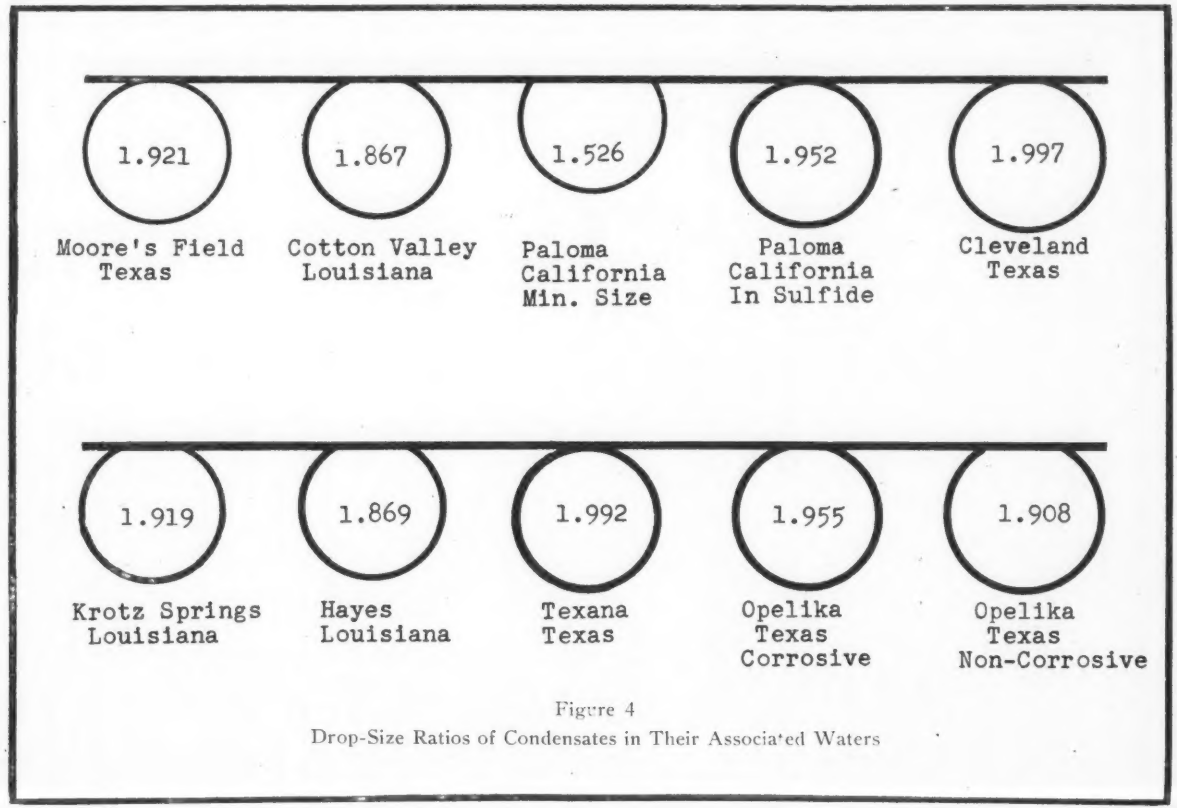


Figure 4
Drop-Size Ratios of Condensates in Their Associated Waters

a smooth surface. This surface is then rinsed in carbon tetrachloride to remove oil or grease. The specimen is then boiled for 10 minutes in a 20 percent sodium-hydroxide solution containing pellets of metallic zinc. The specimen is then rinsed thoroughly with distilled water, dipped in a 10 percent sulfuric-acid solution and again well rinsed with distilled water. The specimen is then placed in the cell containing the aqueous solution or condensate as the case may be, and the oil or water drops placed against the polished surface.

Method of Reading Drop Measurement, Calculating Result

The method of reading the drop measurement and calculating the result is shown by Figure 2. The measurements made are the height and the diameter of the drop. The measurement of the drop-size ratio is $\frac{h}{\frac{1}{2}d}$. [9] The figure shows a drop with the shape of a sphere. In this case the drop material does not wet the steel, and the height is equal to twice the radius (2r). The diameter is also (2r); the ratio;

$$\frac{h}{\frac{1}{2}d} = 2/1 \text{ or } 2.00.$$

If the oil wets to the extent of forming a hemisphere the relation becomes:

$$\frac{h}{\frac{1}{2}d} = r/r = 1.00.$$

The ratio approaches zero as the drop approaches a flat layer.

By visualizing these conceptions it is possible to recognize the corresponding drop shape for any given drop-size ratio.

TABLE 2

Drop-Size Ratios of Condensates and Waters

1. Ratio of Condensates In Well Waters

Condensate	A. Water From Same Well	B. Distilled Water	C. Hydrogen Sulfide Water
Moores Field, Texas	1.921	1.895	1.893
Cotton Valley, La.	1.857	0.646	1.929
Paloma, Calif. (A)	1.767	0.200	1.894
Paloma, Calif. (B)	1.526	0.796	1.952
Paloma, Calif. (C)	1.935	0.320	1.932
Paloma, Calif. (D)	1.730	0.183	1.851
Cleveland, Texas	1.997	.....	.....
Krotz Springs, La.	1.919	1.861	1.929
Hayes, Louisiana	1.869	.....	.....
Texana, Texas	1.992	1.889	1.946
Opelika, Texas	1.955	1.934	1.912
A. Corrosive Opelika, Texas	1.908	1.922	1.888
B. Non-Corrosive			

2. Ratios of Waters In Condensates

	Condensate From Corrosive Opelika Well	Condensate From Non-Corrosive Opelika Well
Water from corrosive Opelika well	1.551 (Rust Spots)	1.262 (Rust Spots)
Water from non-corrosive Opelika well	1.757 (No Rust Spots)	1.546 (No Rust Spots)

Typical Wetting Power of Condensates and Waters in the Presence of Each Other

Figure 3 shows the results of some early studies made to determine the wetting ability of three condensates for 1020 steel in the presence of the water produced with the condensates, and also the wetting ability of three waters when tested in a single condensate. The data for the three condensates are shown in the bottom half of the figure. It will be noted that the drops are almost spherical. The size ratios vary from 1.950 to 2.000. This means that none of these condensates will displace their produced water from steel once it becomes wet with it. The first well is mildly corrosive, the second is non-corro-

sive and the third is corrosive. In none of these cases, however, can any lack of corrosion be ascribed to the ability of the condensate to protect the steel by displacing the aqueous phase.

The upper half of the drawing shows the result of placing water drops from these three wells on steel immersed in condensate from the Texana, Texas, field. It will be noted in this case that the Texana water and the Moores field water, in contrast to the action of the condensate drops, readily displaces condensate from the steel, causing it to become wetted with the aqueous phase. The Cleveland water, however, only partially displaced the condensate and did not wet the steel as readily as did the other two. It will be noted that the Cleveland water, of little wetting power, contains a very small quantity of dissolved salts, only 163 ppm being present. The other two waters contain a much greater concentration of dissolved solids.

It has been found that waters of high dissolved solids tend to wet steel much better than do waters low, or lacking in, dissolved salts. This lack of salts in the Cleveland water, therefore, aids in preventing the same degree of water wetting as obtained by the other two waters. This reduced degree of wetting by the Cleveland water, plus the higher circuit resistance of the corrosion cell formed where the steel is wet both tend to make this well non-corrosive, as found by experience. In studying drop-size ratios of condensates and waters, it is advisable to measure both the drop size of the oil with water as the external phase and that of the water with oil as the external phase, to aid in determining the corrosion rate to be expected by the well metal equipment.

Drop-Size Ratios of Condensates From Various Fields

A series of condensates and waters were obtained from eight fields in Texas, Louisiana and California for study. The analyses of the waters and some data on the wells are given in Table 1. One of these eight fields produces from four zones, and a condensate and water sample was obtained from each. Another of the fields contains two wells completed in the same horizon and apparently of equal properties and flow characteristics excepting that the fluid from one is corrosive and the other non-corrosive. Both wells were included in this study. Measurements were made on all of these condensates of their drop sizes under three conditions:

(1) In the produced water.
(2) In distilled water.
(3) In water containing hydrogen sulfide.

In addition, drop sizes were made of the water from the corrosive and non-corrosive Opelika wells in each of the two condensates.

The object of making drop measurements in the water produced with the oil is obviously to determine the wetting power of the oil under present producing conditions. The purpose of making the measurements in distilled water is to determine the wetting power under water conditions which may have prevailed under early well producing characteristics, when the produced water may have been low in salts. The reason for making the measurements under sulfide conditions is because it has been found in at least two fields that

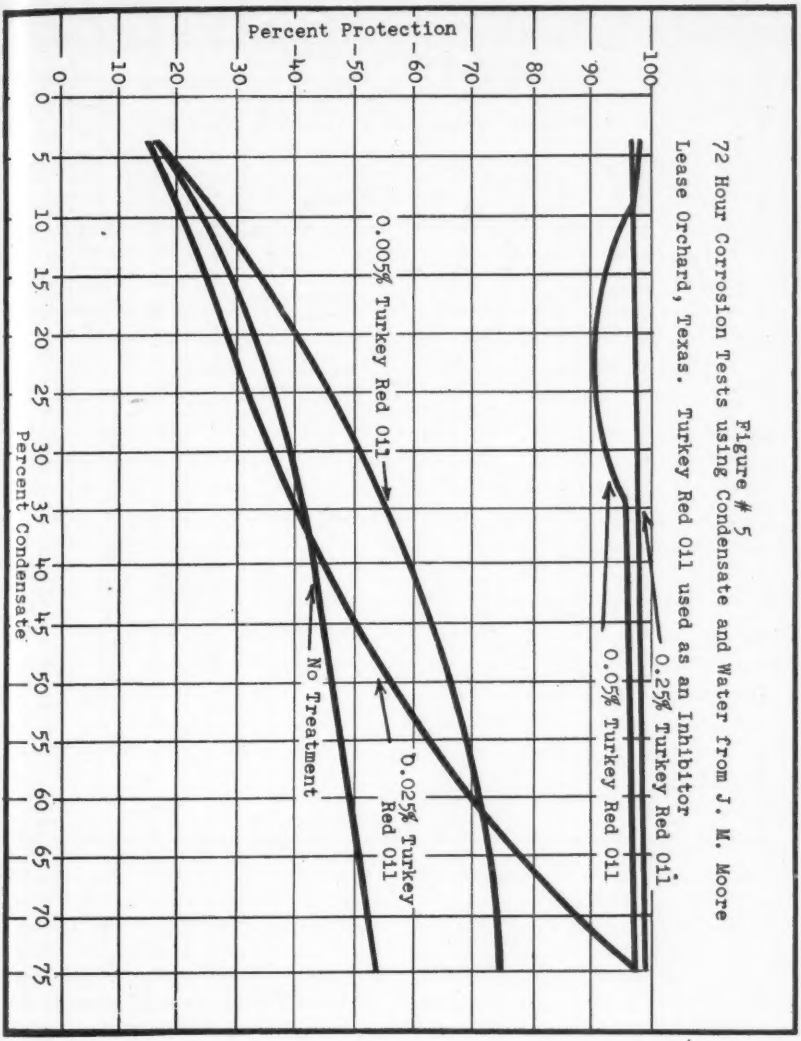
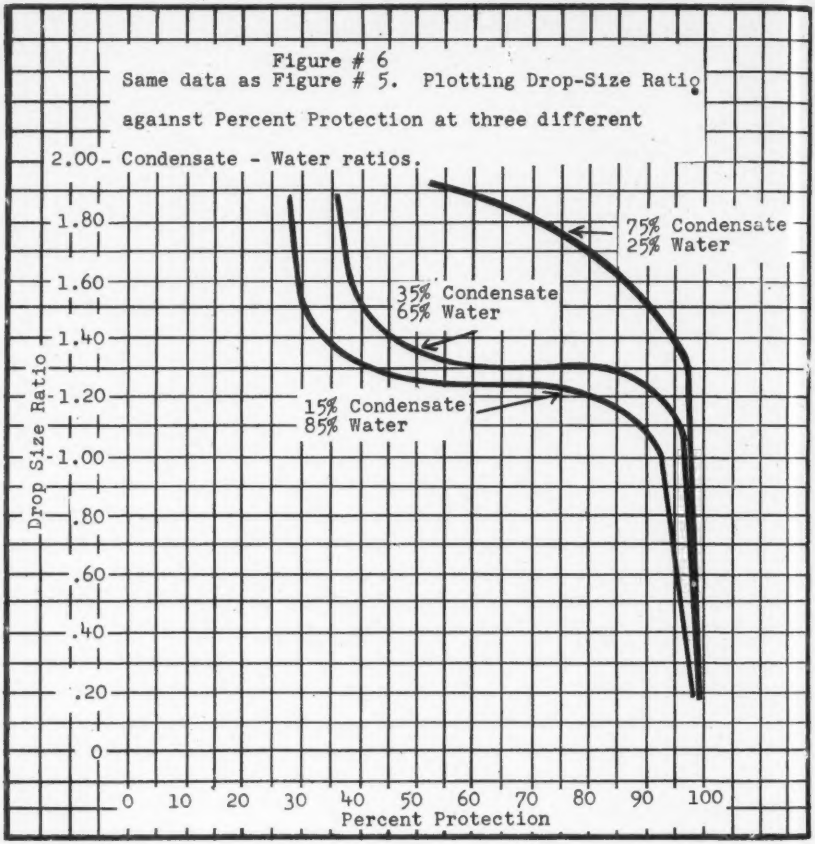


Figure # 5
72 Hour Corrosion Tests using Condensate and Water from J. M. Moore Lease Orchard, Texas. Turkey Red Oil used as an Inhibitor

the presence of only traces of hydrogen sulfide in the gas has developed a film of iron sulfide on the metal equipment, and it is this type of surface that must be wet by the condensate rather than that of a non-sulfide iron surface. This type of corrosion becomes of great importance because it has been shown by Rogers[10] that sulfide corrosion rates at low pH values in the absence of oxygen are very rapid.



A. Wetting Power of Condensates for Steel

The data obtained on this series of tests are listed in Table 2 and partly shown in Figure 4. It will be noted for the condensates measured in their produced water that none of the fields excepting Paloma have any wetting ability. The drop-size values for all fields except Paloma range from 1.867 to 1.997. This means that none of these condensates will displace water from steel and in the presence of both phases the steel becomes water wet. The Paloma field has three wells of some wetting ability, as values of 1.526 to 1.767 were obtained for them. These values, however, are not sufficiently low to furnish much protection. It will be especially noted that the corrosive and non-corrosive Opelika condensates have similar wetting angles, in that both are above 1.900. From this it is concluded that their differences in corrosion rate are not linked with the composition of the condensates.

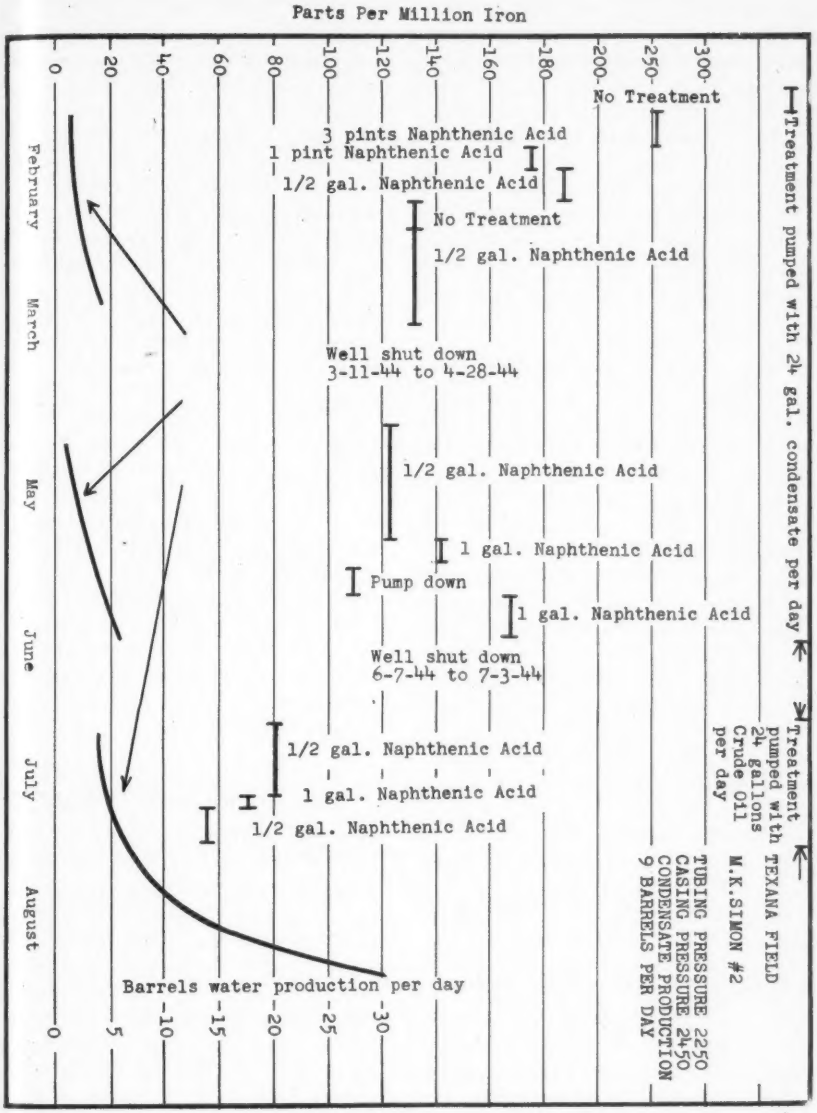

Parts Per Million Iron
0
20
40
60
80
100
120
140
160
180
200
250
300
No Treatment
3 pints Naphthenic Acid
1 pint Naphthenic Acid
1/2 gal. Naphthenic Acid
No Treatment
1/2 gal. Naphthenic Acid
Well shut down
3-11-44 to 4-28-44
1/2 gal. Naphthenic Acid
1 gal. Naphthenic Acid
Pump down
1 gal. Naphthenic Acid
Well shut down
6-7-44 to 7-3-44
1/2 gal. Naphthenic Acid
1 gal. Naphthenic Acid
1/2 gal. Naphthenic Acid
February
March
May
June
July
August
Barrels water production per day
0
5
10
15
20
25
30
Treatment pumped with 24 gal. condensate per day
Treatment pumped with TEXANA FIELD 24 gallons Crude Oil per day
M.K.SIMON #2
TUBING PRESSURE 2250
CASING PRESSURE 2450
CONDENSATE PRODUCTION
9 BARRELS PER DAY

Figure 7

For the measurements made in distilled water, the condensates from Paloma and Cotton Valley gave very low ratios. The measurements were found to lie in the range 0.183 to 0.796. These indicate extremely good wetting power, sufficient to offer excellent protection. If at any time these wells produced distilled water or water low in salts, undoubtedly the corrosion rate was low, both because of the high wetting power of the oil and because of the low corrosion rate of such a water. The difference between the wetting power of these oils in distilled water and in their present produced water shows how a change in corrosion rate can accompany a change in water composition, with all other factors remaining constant.

The measurements made in sulfide bearing waters show the condensates to have little or no wetting power under this condition. This has been found to be true also in other studies made on crude oils. Corroded surfaces of metal equipment from producing wells should be carefully examined for sulfide films as they may explain high corrosion rates not normally expected.

In general, it is seen that none of the condensates tested have much wetting power and it is apparent that the metal equipment in these wells tends to be water wet at all times.

B. Wetting Power of Water for Steel

In the case of the two Opelika wells measurements were made of the ability of the water from each well to wet the steel in the presence of each condensate. The data are given in Table 2. It will be noted that the water from the corrosive well and that from the non-corrosive well displaced both condensates. The water drop-size ratios varied from 1.262 to 1.757. This again demonstrates the relatively great ease with which waters wet the metal equipment of condensate wells. This alone, however, does not explain the difference in corrosion rates. It was found, in addition, that the water drops from the corrosive well developed rusty areas on the steel whereas the water from the non-corrosive well did not. Reference to the water analyses from these two wells in Table 1 shows the reason. The water from the corrosive well is higher in dissolved solids than is the non-corrosive water. This means a lower circuit resistance for the corrosive water, allowing corrosion to proceed more rapidly. Thus while in both cases the water wets the steel, in one case the water film is corrosive whereas in the other case it is not. When the water from the non-corrosive well becomes equal in composition to the water from the corrosive well it too will be corrosive.

Laboratory Corrosion Tests

Inasmuch as the condensates used in this study had little wetting ability, a series of laboratory corrosion tests were made to determine whether they would be protective if they could be made to preferentially wet steel. It has been found that small additions of such materials as naphthenic acids, sulfonated castor oil (Turkey Red Oil), etc., increases the wetting power of these condensates; and Turkey Red Oil was used as an additive.

The apparatus for the corrosion

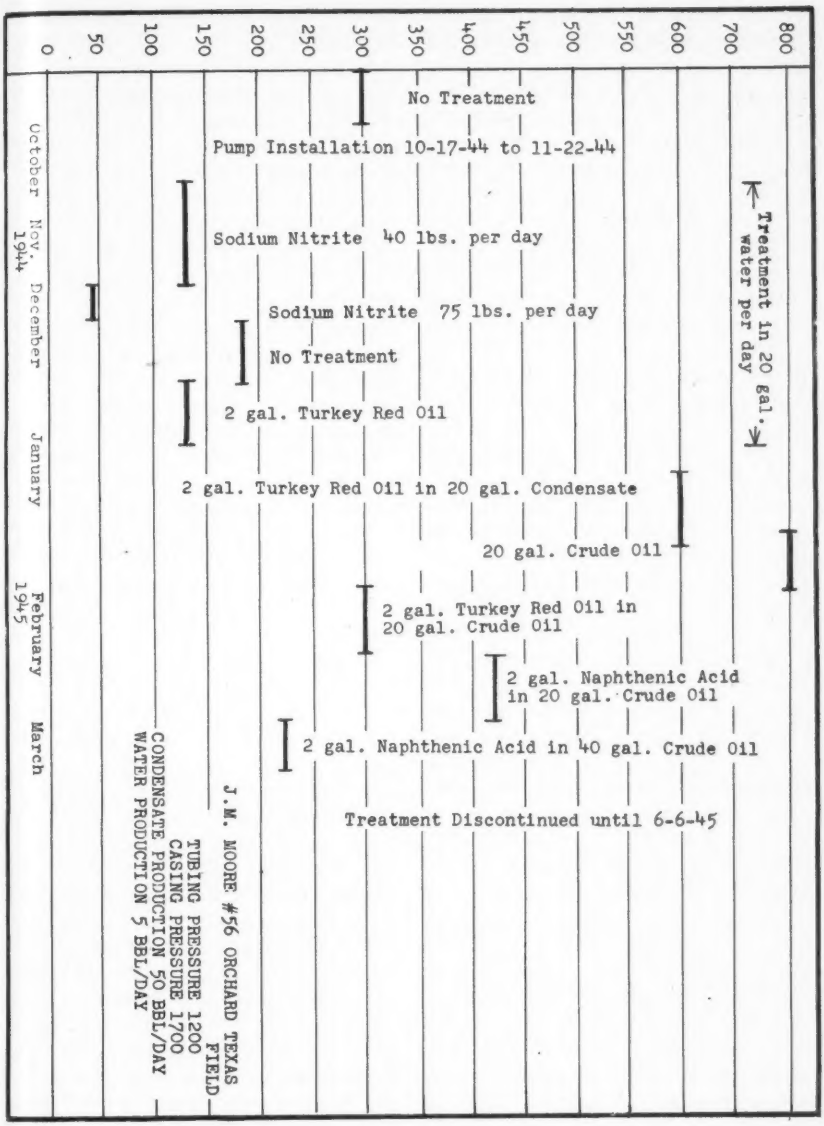

0
50
100
150
200
250
300
350
400
450
500
550
600
700
800
October
Nov.
December
January
February
March
1944
1945
No Treatment
Pump Installation 10-17-44 to 11-22-44
Sodium Nitrite 40 lbs. per day
Sodium Nitrite 75 lbs. per day
No Treatment
2 gal. Turkey Red Oil
2 gal. Turkey Red Oil in 20 gal. Condensate
20 gal. Crude Oil
2 gal. Turkey Red Oil in 20 gal. Crude Oil
2 gal. Naphthenic Acid in 20 gal. Crude Oil
2 gal. Naphthenic Acid in 40 gal. Crude Oil
Treatment Discontinued until 6-6-45
Treatment in 20 gal. water per day
J.M. MOORE #56 ORCHARD TEXAS FIELD
TUBING PRESSURE 1200
CASING PRESSURE 1700
CONDENSATE PRODUCTION 50 BBL/DAY
WATER PRODUCTION 5 BBL/DAY

Figure 8

test consists of a machine that vigorously shakes a wide-mouth, French square bottle containing a prepared weighed steel specimen, together with the water and condensate being studied. The shaking machine is essentially a double action reciprocating horizontal shaker, with just enough vertical motion or rocking to produce a turbulent motion of the liquids. With a condensate - water mixture, both liquids are brought in contact with the test specimen. The machine has two trays, each holding nine eight - ounce bottles. When found necessary, three additional bottles were secured on top, giving 21 tests.

The specimens used consist of 1" x 4" 20-gage plates with corners turned down ¼". The weight of a specimen is between 15 and 20 grams. The turned-down corners act as legs, holding the test piece off the bottom of the bottle. After a test, the specimens are thoroughly cleaned, dried and weighed; and the weight loss determined. The specimens are then pickled in 10 percent sulfuric acid for a few hours, rinsed and dried. They are then weighed and kept in a desiccator until used again. A shaking time of 72 hours is used.

The corrosion studies were made using the following percentages of oil based on the entire condensate-water mixture: 0%, 3.5%, 7.5%, 15%, 35% and 75%. Twenty-five milliliters of water was used in all tests and become, respectively, 100%, 96.5%, 92.5%, 85%, 65% and 25% of the total fluid. Each of the above ratios was tested without any inhibitor and with 0.005%, 0.025%, 0.05% and 0.25% Turkey Red Oil. The condensate and water used for this test came from Moores field, Texas, and were from a corrosive well.

The results of the tests, showing the percent of protection obtained for each treatment with inhibitor, are plotted in Figure 5. It will be noted for the series of condensates without treatment that, as the condensate increased from zero to 75%, that the amount of protection increased from zero to 53%. Thus, although the condensate has no preferential wetting qualities, increasing its percentage reduces the corrosion rate. This is probably due to the mass effect of the condensate allowing the metal surface to be bathed by increasing quantities of condensate, resulting in contact with the metal of decreasing quantities of fresh corrodent. It will be noted that for 0.05% Turkey Red Oil and above, that 95% protection was obtained for all condensate percentages.

The data from this test have been plotted in a slightly different manner in Figure 6. Here the drop-size ratio for three condensate percentages has been plotted against percent protection. It will be noted that for drop-size ratios above 1.000 that the percent condensate plays an important part; and the greater the percentage, the less the corrosion. For drop-size ratios of 1.000 and below better than 90% protection was obtained, regardless of the percent of condensate present. Here again is demonstrated the importance of another variable in condensate corrosion, i.e., as the water percentage increases the corrosion rate likewise increases for drop-size ratios above 1.00, which covers all condensates tested in this study.

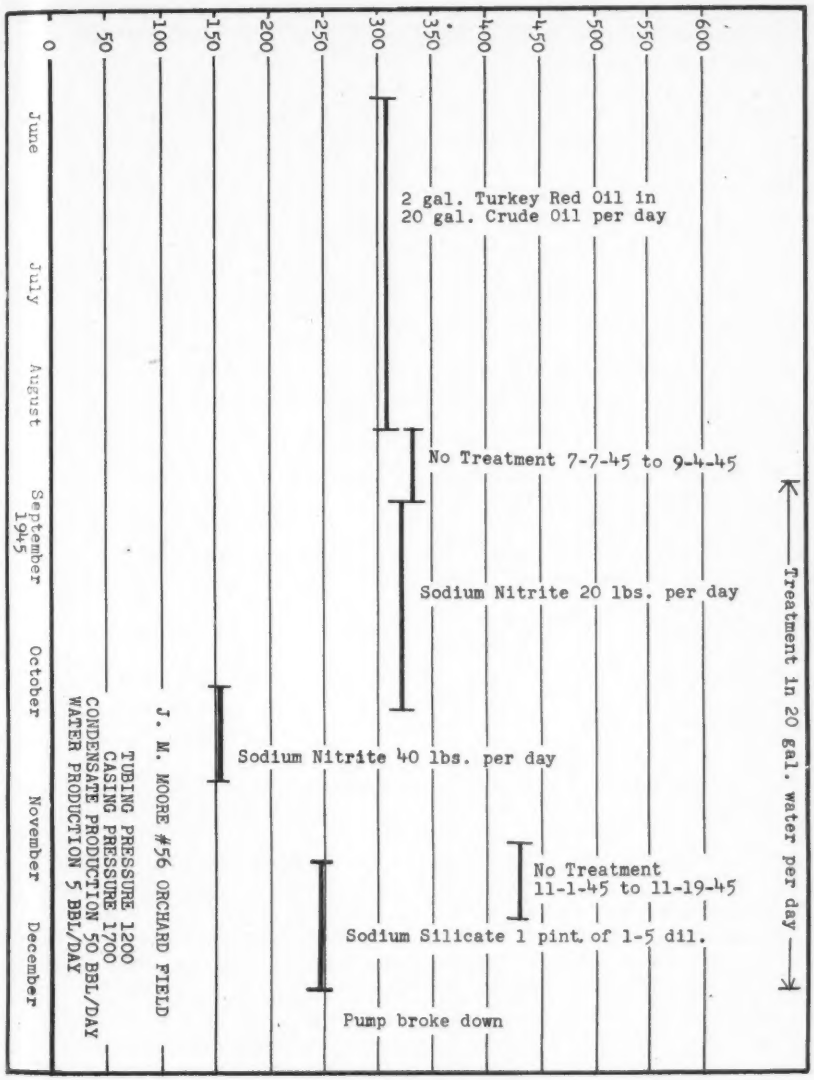

0
50
100
150
200
250
300
350
400
450
500
550
600
June
July
August
September
1945
October
November
December
J. M. MOORE #56 ORCHARD FIELD
TUBING PRESSURE 1200
CASING PRESSURE 1700
CONDENSATE PRODUCTION 50 BBL/DAY
WATER PRODUCTION 5 BBL/DAY
2 gal. Turkey Red Oil in
20 gal. Crude Oil per day
No Treatment 7-7-45 to 9-4-45
Sodium Nitrite 20 lbs. per day
Sodium Nitrite 40 lbs. per day
No Treatment
11-1-45 to 11-19-45
Sodium Silicate 1 pint of 1-5 dil.
Pump broke down
Treatment in 20 gal. water per day

Figure 9

Field Tests of Corrosion Inhibitors

Field tests have been made on two wells to determine whether the beneficial results obtained in the laboratory with wetting agents could be duplicated on corrosive wells. In addition, tests with other inhibitors have been made.

The wells selected had open-end tubing not packed against the casing, allowing the treatment to be pumped into the well annular space and produced up the tubing with the production. The chemical was prepared by mixing the inhibitor in a 55-gallon drum using condensate, oil, or water as required and pumping from this reservoir into the well. The pump used was an electrically driven Hills-McCanna Type UMIF reciprocating plunger pump. This pump had a maximum discharge pressure of 5000 psi. The amount of material pumped was varied at either 20 to 24, to 40 gallons per day. In most cases the smaller quantity was used.

The first test was made on a well in the Texana, Texas, field. The data obtained are given in Figure 7. In this test, the treatment consisted of pumping 24 gallons of condensate per day containing anywhere from one pint to two gallons of naphthenic acid. During these treatments it was found that the iron content of the water dropped from 385 p.p.m., to 110 to 190 p.p.m. During this time, drop-size ratios were determined daily on the produced condensate and were found to vary from 0.500 to 1.700. The failure of the iron to be reduced to zero is believed due to the phenomena of recombination of the condensate with the high pressure gas phase in the well. If the 24 gallons of condensate re-entered the gas phase, the remaining liquid of one pint to two gallons of naphthenic acid would be insufficient material to coat the tubing and give protection except perhaps to the upper portions of the tubing, the Christmas tree and flow lines where the amount of condensate deposited becomes appreciable. To test this point, an injection was made of the wetting agent in crude oil. In this case one-half to one gallon of naphthenic acid was injected along with 24 gallons of 24.8° API gravity crude oil. It will be noted that the iron content fell to 56 p.p.m. This is taken to mean that the crude oil-naphthenic acid mixture remained in the liquid form and wet the tubing with a protective coating.

The second series of tests were made at Moores field on a corrosive well using the pumping equipment from Texana. These data are shown in Figures 8 and 9. The iron content of this fluid without treatment ranges from 275 to 300 p.p.m. The first treatments were with sodium nitrite. Very large amounts were necessary to obtain appreciable reductions in iron content. Forty pounds per day reduced the iron to 130 p.p.m., while 75 pounds per day reduced it to 45 p.p.m. To test these results, longer time treatments were made during September and October. At this time, 20 pounds per day only reduced the iron to 275 p.p.m. and 40 pounds cut it to 155 p.p.m. as before. Since these data indicated 75 pounds per day at a cost of $11.25 per day was necessary, the cost was considered exorbitant and the tests stopped.

Tests were also made using Turkey Red Oil in water, condensate and crude oil. In these cases, the

iron content fluctuated widely and no protection could be considered as obtained. Naphthenic acid was also used in crude oil, but no beneficial results were obtained. The drop-size ratios of the condensates collected in the low pressure separator were measured and found to be below 1.000. Since this constitutes sufficient wetting to insure protection, it is believed that insufficient condensate is precipitated in the well to allow a protective layer to be formed on the tubing excepting perhaps the upper portion, the Christmas tree and the flow lines.

Summary and Conclusion

A study has been made of the wetting power of condensates and waters for steel in the presence of each other. This has been done both with and without the addition of wetting agents and the resulting effect on the corrosion rate of the mixture studied by laboratory methods. In addition, the testing has been extended to field operations. It is concluded that:

1. None of the condensates from the eight fields tested have sufficient wetting power to displace their present produced water from steel, and as a consequence are non-protective and do not prevent the steel from being water wet except as noted in item 2.

2. Some protection is obtained from fluids of high condensate percentage due simply to the mass effect of large amounts of condensate and small amounts of water.

3. The aggressiveness of the aqueous phase produced with the hydrocarbon governs the corrosion rate. The corrosion rates experienced by the wells studied in this report must be examined from the standpoint of the corrosiveness of the aqueous phase, rather than from the standpoint of the protectiveness of the hydrocarbon phase. If the aqueous phase is present in appreciable amounts and is corrosive to steel in the absence of the condensate, corrosion will take place and, if not, no corrosion will occur in the well.

4. The corrosion rate of a well can increase as the salt content of the aqueous phase increases, or as the water percentage increases.

5. Laboratory tests show that the corrosion rate can be decreased by increasing the wetting power of the oil through the use of addition agents. The corrosion rate obtained for drop size ratios above 1.000 depend upon the percent water produced. For drop sizes below 1.000, all condensates tested at concentrations as low as 15 percent condensate were protective.

6. The extension of the use of wetting agents to producing wells did not give the same beneficial effects as found in the laboratory.

7. The use of sodium nitrite was found to be uneconomical as a corrosion inhibitor.

The authors wish to thank the executive department of the Gulf Oil Corporation for their kind permission to publish these data.

References

1. T. S. Bacon and E. A. Brown, Corrosion in Distillate Wells, NGAA April, 1943.
2. F. W. Jessen, A Study of Corrosion in Gas and Condensate Wells in the Katy Field, Texas. Proc. 1st Annual Meeting NACE, April, 1944.
3. W. F. Rogers, Some Studies of Waters Produced by High Pressure Wells, Proc. 1st Annual Meeting NACE, April, 1944.
4. Paul Menaul, Announcement at Spring Meeting API Houston, May, 1944.
5. Minutes of NGAA Corrosion Research Project Committee, 1945.
6. Minutes of NGAA Corrosion Research Project Committee, 1945.
7. H. T. Griffin and E. C. Greco, 2nd Annual Meeting NACE, May, 1945.
8. API Symposium on Corrosion of Gasoline Pipe Lines. 24th Annual Meeting of API, 1943.
9. G. A. Mack and D. A. Lee, Determination of Contact Angles from Measurements of the Dimensions of Small Bubbles and Drops: II—The Sessile Drop Method. Journal of Physical Chemistry, 40, 159 (1936).
10. W. F. Rogers and W. A. Shellshear, Corrosion of Steel by Oil Well Waste Waters, Industrial and Engineering Chemistry, Vol. 29, 160, 1937.

Discussion

By T. S. Bacon

Lone Star Producing Company, Dallas, Texas

I certainly enjoyed this paper. I do want to make one or two comments. Wettability is a very interesting proposition to me. We became interested in it on the basis of our well-head test coupons. It seems there are quite a few factors that probably occur in field equipment that are subject to lack of reproducing in the laboratory. Water phase samples should reach the laboratory close to their well-head conditions. The hydrocarbon liquid phase is necessarily very different by the time it reaches the laboratory from its actual condition in the well, due to change in temperature and pressure. The condition of the metal surface also has a lot to do with the thing, and our well-head coupons were of interest in that connection.

The early coupons from the noncorrosive well, for example, showed no water wettability. We would take those coupons out of the wellhead and pour water on them. The water would run around on the surface just like drops of mercury, with no wetting of the metal surface. Coupons from corrosive wells showed water spreading out in a nice, uniform film over the coupon. So we had high hopes of a wettability explanation of this thing. Subsequent observations on wettability failed to correlate with the corrosiveness of the various wells, and in fact we found a few coupons, (and these coupons are only one inch wide by eight inches long) that would be

water-wet on one end and not subject to water-wetting on the other end. I don't know why we got that discrepancy on that supposedly uniform metal surface, but we did.

I would like to emphasize the importance of coupons in evaluating corrosion rates rather than the iron content of well-head water samples. We found our non-corrosive wells often run more than 100 parts per million of iron in the well-head water samples, and I believe a good many of Mr. Rogers' points, when inhibitors were added, were below 100 parts per million of iron. Dissolved iron is an indirect measure of corrosion, whereas the well-head coupons are a direct measure at their points of installation.

In regard to the question of salt content of distillate well waters and its relation to corrosion, which has been mentioned in this paper and also by Mr. Speller, the NGAA work on well-head water analyses has presented some data that perhaps should be considered before too definite conclusions are drawn regarding increase in corrosion rate with increase in chloride or salt content. Specifically, Bateman Lake, Louisiana, shows 354 parts per million of chloride; Katy, Texas, showed traces, or zero chlorides. The Opelika Field shows 707 parts per million chlorides. These fields are all corrosive. Non-corrosive fields include La Gloria, showing 4000 p.p.m. of chlorides; Rodesa, Louisiana, showing 1000 p.p.m., and La Rosa, showing 44,000 p.p.m.

So we can't conclude on that information that chlorides alone will aggravate corrosion seriously.

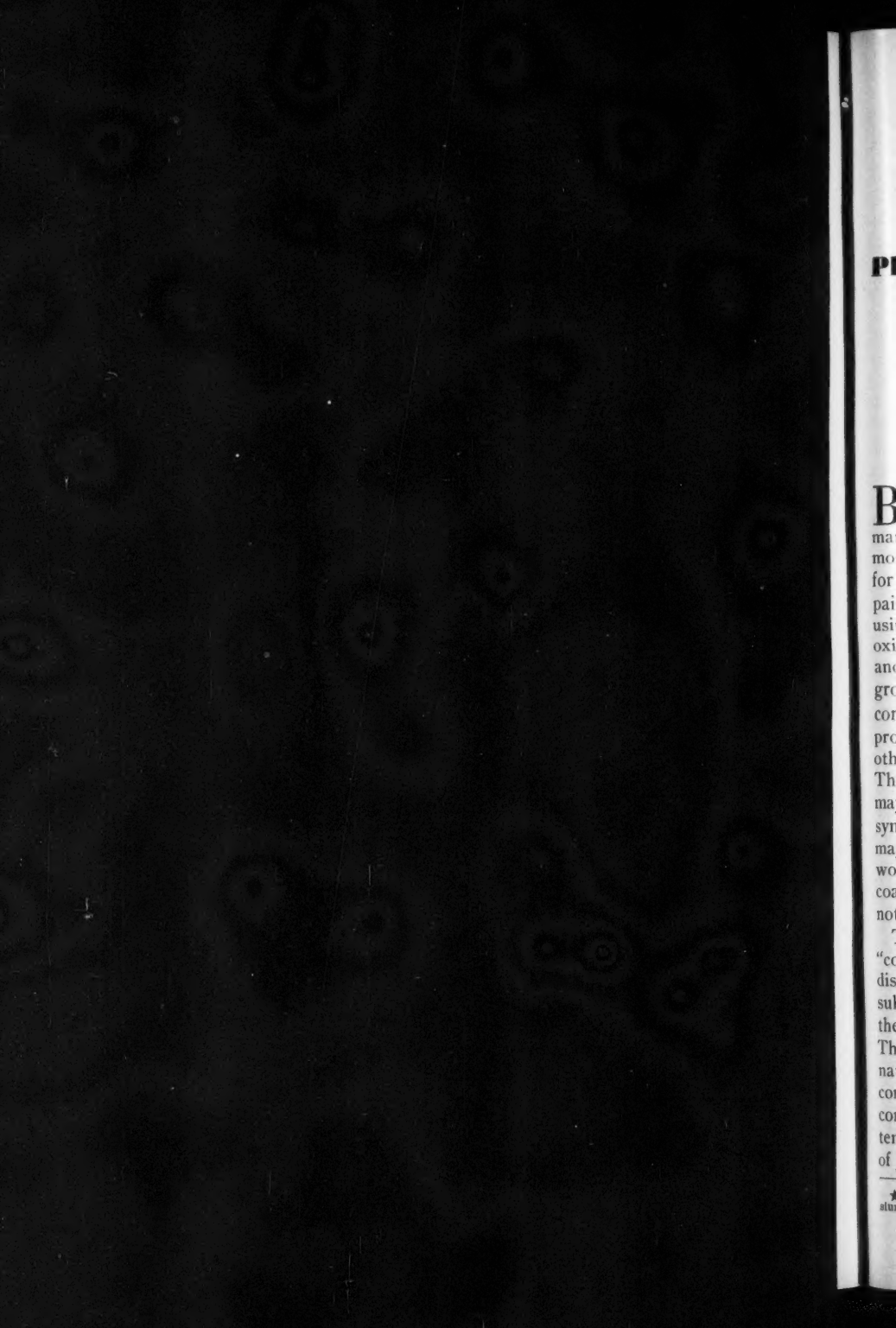
Discussion

By Dr. Norman Hackerman
Associate Professor of Chemistry, University of Texas, Austin, Texas

In my opinion the authors have done a fine piece of work and are to be commended for focusing attention on a point too often overlooked in corrosion research. There are some differences of opinion which come to mind, however.

The outstanding point to be considered in connection with this work is the fact that the sessile drop and laboratory corrosion experiments were performed in the presence of air. It is not at all unlikely that the wetting of the steel by the condensate differs considerably under the anaerobic conditions which obtain in the wells.

In some experiments performed in this laboratory, it was found that drops of condensate from the non-corrosive well in Opelika Field spread on distilled water to a considerably greater extent than did condensate from the corrosive well in the same field. The actual amount of spreading of either condensate was variable with the time at which the sample was taken and also with the age of the sample. However, qualitatively the difference specified



Plastic Coatings to Control Metal Corrosion—A Review*

By S. P. Wilson
Technical Director, Varnish Products Company, Cleveland, Ohio

BY RESTRICTING our discussion of plastic coatings, we omit many of the most widely used and most important protective coatings for metal. These include the many paints and oleoresinous materials using red lead, zinc chromate, iron oxides, metallic aluminum, lead, zinc and copper, as well as the whole group of asphaltic and bituminous compounds so largely employed as protective coatings for pipelines and other large-scale metal projects. These work-horses of the industry may lack the glamour of the newer synthetic plastic materials and they may be replaced by them in time, but it would give a distorted picture of the coating field if their importance were not mentioned.

There are many definitions of "corrosion." For the purpose of this discussion I shall define it as the resultant of the combined effects of the environment upon the metal. These systems vary tremendously in nature, and the requirements for corrosion-resistant coatings vary accordingly. We may have such a system as your car in the environment of your city's atmosphere, or we may have a boiler-tube operating at 212° F. with varying water-hardness. The system might be a silver-plated dial operating in humid air containing traces of hydrogen sulfide, or it might be a chemical reactor containing hot hydrofluoric acid, a refrigerator cabinet subject to humidity, grease or organic acids; a steel cartridge case operating under gun-breach conditions, or a tin can designed to contain a dilute solution of alcohol in water, saturated with carbon dioxide and flavored with lupulin, commonly known as beer.

In addition to the severity of conditions in the system, the choice of coatings must be affected by a variety of other factors. These will include applicability of the coating under production conditions, decorative requirements for the coating, all-over comparative cost, toxicity, and required duration of resistance to the environment. From the many materials now available, together with those which will surely emerge from the laboratories in the future, the engineer will choose on such a combined basis of evaluation. Intrinsic superiority in corrosion resistance is not sufficient, e.g. a tarry mass of infinite chemical resistance

* A paper presented at the Corrosion Symposium, Cleveland, Ohio, September 21, 1946.

would hardly do for a washing machine, nor would a superlative chemical resistance permit a toxic material to be chosen for a food container. All the factors must be weighed and applied to the final choice.

Although there are literally hundreds of polymerized and polymerizable chemicals that fall under the heading of plastics, they may be classified under two main headings. These are the thermosetting, or heat hardening, types on the one hand and the thermoplastic, or heat and pressure softenable materials on the other. A few materials are borderline cases, acting as members of both groups. The thermoplastic materials are as a rule completely polymerized as made, and are deposited from solution or suspension without further chemical change being involved. The thermosetting products are used in a partially converted condition, the final curing to an insoluble, infusible, corrosion resistant film being obtained after application by baking.

The oldest member of this group is the condensation products of phenol and formaldehyde. When this reaction is carried to its limit, an insoluble, infusible resin results, very useful as a structural material but not as a coating. The reaction can be interrupted, however, at a point where the resin is soluble in alcohol and this can be applied to a surface on which the final conversion can be achieved. The converted film rates very highly in regard to corrosion resistance against a wide array of chemicals.

One Navy specification for such a product demands resistance for 5,000 hours to such individual tests, as, moving sea-water, hot oil at 200° F., water at 212° F., acetone at 70°, alcohol at 70°, gasoline 70°, and toluol at 70°. It also required adhesion without film rupture if heated to 450° for ten hours or kept at 50° for 100 hours. Among other specification tests for this type of coating may be included resistance to lacquer thinner at 100° for seven days, tenth-normal HCl and tenth-normal NaOH for 72 hours. Resistance to organic acids, ammonia, salts and most organic solvents is excellent.

This type of coating can be applied by dip or spray from an alcoholic solution at from 20-30 percent solids, giving a dry film of 0.5-0.75 mil thickness. The baking schedule varies with the number of coats required and the degree of chemical resistance desired; the higher the temperature the higher the resistance. Longer time of bake is only partially equivalent to higher temperatures. A good average schedule for one coat is 325° F. for 40 minutes.

This requirement for high temperature and time being adverse to some large-scale potential applications work has been carried on to shorten this. For some objects, notably metal pipe, the use of induction heating and dip coats makes possible continuous rapid coating—the bake being shortened to around five minutes. Pipe so coated has been given field tests of four to six years in corrosive soils with success, while boiler-tubes operating at 212° F. inside and 675° outside have stood up three years satisfactorily. For coating large vats and other articles not amenable to ordinary oven bake or induction heating, either current

of super heated air, or portable infrared lamps may be used.

The drawbacks to this type of finish are its deep amber color which precludes: the manufacture of white or pastel colors, and the long critical bake. In addition the film is very hard and somewhat brittle, particularly if overbaked. Its use, therefore, is largely confined to places where intrinsic chemical resistance is required and where no pigmentation, or dark colors, are required. Such additional uses are aluminum spinning bobbins for rayon plants, containers for corrosive chemicals, such as mustard gas, etc.

Where the decorative element is important, and where chemical resistance need not reach the maximum level, another group of thermosetting plastics becomes of prime industrial value. These are the amine-formaldehyde resins, condensation products of formaldehyde and amino resins such as urea or melamino. Condensed with higher alcohols such as butyl or capryl, water white resins, soluble in aromatics and heat convertible to a colorless film are obtained. If used alone, films of great hardness, but poor adhesion and gloss are obtained, so they are usually modified with drying or nondrying alkyd resins or other plasticisers. The chemical resistance is usually diminished by these additions, but the improvement in other factors warrants this in most of their applications. These resins appear on most of our home appliances, such as refrigerators, washers, steel kitchen cabinets, fluorescent reflectors, etc. They afford a complete choice of color, particularly non-yellowing whites, give tough durable films at bakes as short as one minute at 400° F. on thin steel, or three to six minutes under infrared on regular production. Their chemical resistance is high against humidity, fruit acids, mild alkalis and detergents, and fats and oils. They are flexible enough to permit coating steel strip and winding in coils for making venetian blind slats. Industrially these are of prime importance, and as of today offer perhaps the best choice for finishing mass production steel articles to be used in ordinary environments.

The last member of the thermosetting resin family is potentially the most interesting. This is the silicone group-resins derived from silicon linked to carbon complexes. These are links between the inorganic ceramics and the organic coatings and give a new order of magnitude to resistance to heat and most chemicals.

The silicone coatings come as solutions in aromatic solvents. They may be pigmented, and a white made with titanium oxide is unchanged at temperatures above 400° F. at which the best melamine alkyd products are appreciably discolored. They are very resistant to fruit juices, iodine, ink and boiling water, but aromatic and some chlorinated solvents attack them to some extent. Silicone finishes have stood up to 100 hours in 3 percent NaOH at 100° F. with only slight loss in gloss. They have also withstood 3 percent HCL for 100 hours, 3 percent acetic for the same period, and oleic acid at 212° F. and hot mineral oils for the same time.

Silcones require more baking than the usual run of industrial finishes, an hour at 350° F. being typical. This

is a disadvantage, while the present high cost, approximately $25 a gallon against $3 for a good melamine enamel, restricts the use of silicone to places where its intrinsic integrity to heat and chemicals is absolutely required. The cost is bound to come down as production increases and the resistance to chemicals and weathering connected with these finishes is certain to become more widely employed.

The thermoplastic resins are far more numerous than the thermosetting. They can, however, be broadly separated into a few classes. The two most important are the cellulosic and the vinyloid divisions, in each of which many sub-classes of chemicals individuals and copolymers demand mention. Those are all high-polymers, wither natural as in the cellulose compounds, or artificially made as in the vinyloid series. The coating consists of a solution or suspension of these high polymers and application by dip, spray, roller-coat or other means applies the film so that an air dry or lowbake to remove solvents is adequate. Heat for converting the compound is not required, although in some of the vinyloids a fairly long bake is required to give necessary dryness, smoothness and adhesion. These films will resoften with heat, in contrast to the preceding series.

Among the cellulosic plastics the oldest and most important is nitrocellulose. Many millions of gallons of nitrocellulose lacquers are used annually in finishing metal articles ranging from automobiles to glove-buttons. A full discussion of these lacquers is impossible in the time available, but the advantage may be briefly summarized.

Nitrocellulose, with its modifying resins, plasticisers and stabilizers is soluble in a wide range of organic solvents. It may be colored with dyes or pigments to any desired effect or used clear as a coat for silver, brass or copper to resist tarnish. It dries in the air at room temperature faster and more completely than any other industrial finish and gives protection against ordinary environments to a degree adequate for such important products as automobiles. Adhesion to clean metals is good, and is bettered by suitable primers. Chemical resistance is not of the maximum degree, but good against aromatic and chlorinated solvents and alcoholic beverages.

These lacquers are attached by alkalies, and particularly by ammonia. They are also not overly stable against heat, nor, in the unpigmented form, against sunlight. Their value is for industrial finishing, where chemical resistance requirements are moderate, production requirements high, baking facilities undesirable or unavailable and decorative requirements of importance. They and the amine-resin finishes are the two most important coating types at present employed for industrial finishing.

Some other esters of cellulose are employed to a limited degree. The acetate has high moisture and light resistance but its solubility and miscibility with modifiers are very limited. These are more suitable in the cellulose aceto-butyrate and aceto-propionate lacquers, which are less insoluble and more sun-and-heat resistant. An interesting corrosion-resistant application is the protection of bronze statues, screens, store fronts, etc., against the green tar-

nish ordinarily encountered in weathering.

A special case is the use of low solvency mixtures whereby a gel is formed. This gel becomes fluid at about 150° F. cools to 120° F. and an object immersed therein, withdrawn and cooled acquires a very heavy film, equivalent to ten or more sprayed coats. One present application is to aluminum airplane steering wheels. Such a gel has been made using cellulose acetate-butyrate isopropyl alcohol and xylol.

The esters of cellulose are of increasing importance. Ethyl cellulose is available in large amounts, is soluble in almost all organic solvents and dries like nitrocellulose, with which it is often combined in special lacquers. The chief points of superiority are greater resistance to heat and alkali, the chief defect is the above mentioned solubility as well as its inherently softer film. By far the most important application of ethyl cellulose is its use in hot molten coatings, developed during the war to permit the shipment of delicate metal parts under rigorous climatic conditions. Mixtures of ethyl cellulose, mineral oil, waxes and resins have been made that melt at around 375° F. to a reasonably thin fluid with no volatile solvents being required. A metal object dipped in this, withdrawn and cooled develops a coat of from 10-20 mils, incredibly resistant to salt water, humidity, alkalis and acids. The film has no adhesion and can be easily peeled off. Very wide application for shipment and storage of precision metal parts is foreseen.

Most of the war products used dark colored modifiers, but it is possible to make this peelable plastic in almost water white form, suitable for display and sale of the object. Benzylcellulose is known and has had some limited use, but so far is not of industrial importance. The present low price and abundance of toluol may make benzyl chloride, and hence benzylcellulose, more available, and its qualities indicate some definite uses for it in protective coatings.

The above compounds are based on the naturally polymerized cellulose molecule. The vinyloid group includes a very great number of high polymers made from gaseous and mobile liquid monomers by the action of catalysts, often in emulsion form and sometimes combined with heat and pressure. The vinyloid group includes many of the best known plastics, such as the vinyl chloride-acetate copolymers, the acrylic and methacrylic ester polymers, the styrene and synthetic rubber products, vinylidene chloride and acrylonitrile materials, polyethylene plastic, and the allyl phthalate resins. They are characterized by the presence of the vinyl group CH_2: CHR. If R is H, we have thylene, if it is Cl we have vinyl chloride, if it is phenyl, we have styrene and so on. The monomers are made by various chemical reactions, usually from acetylene or ethylene as raw materials.

The monomers are polymerized, usually in emulsion with a catalyst such as benzoyl peroxide. Often two different monomers are polymerized together, giving the copolymers such as vinyl-chloride and acetate and the butadiene styrene couples. When prepared these materials are widely different in solubility and

other characteristics, despite their chemical similarity.

The most widely used vinyloid, for protective coatings are the vinyl chloride-acetate copolymer. These are made in a range of polymerizations, from a molecular weight of 4000-10,000 and in a range of varying percentages of the components. In general, the higher the molecular weight and the higher the chloride percentage the greater the chemical resistance, and the poorer the solubility and adhesion. In the formulation of practically all protective coatings we find it necessary to compromise—to gain flexibility we sacrifice some hardness, to gain durability we may give up some clarity, to gain adhesion we sacrifice chemical resistance, etc. The best solvents for these resins are the ketones such as acetone, methylethyl ketone, methylisobutyl ketone, cyclohexanene and isophoroene. After solution is made in these solvents, the nitroparaffins that have recently entered the field, substantial dilution with cheap aromatics is possible.

The solutions run to the viscous side and high concentrations at spray or roller viscosity were not available till recently. Now by dispersing these resins as organosols in nonsolvents, they may be applied at solid contents of 50 percent or higher, and the aggregation of small particles left as the solvent dries can be flash baked to cause fusion to a smooth coherent film. This principle may find further adaptation to the still less soluble resins now beginning to appear.

The chemical resistance of these coatings is very high. They are attackable by their solvents, and are not recommended for use where aqueous solutions over 140° F. are encountered for long periods. They have some heat instability on iron, zinc and tin surfaces and if in contact with these require stabilization, usually with lead compounds. In the classic case of the beer-can, lead was barred by toxicity, so an oil primer was developed to shield the vinyl coating from the tin and to better the adhesion. In themselves these materials are non toxic and thus offer great opportunities for the finishing of food and cosmetic containers.

Although drying by evaporation, the elimination of solvent and the fusing of the resin require fairly high temperatures for a few minutes, actually entailing the equivalent of a bake. However, where it is not essential to get perfectly dry nonblocking surfaces these may even be brushed and air dried with success. Much of this plastic is applied to sheet metal by rolling, the metal being later shaped into its final form. The vinyl resins, properly formulated and applied, have done very well in this form.

Very recently a very large and interesting application for the vinyloid resins has appeared. It was desired to wrap up large quantities of weapons and instruments held by the armed forces in such form that years later they could be easily and quickly put in service. To this end, the large irregular shapes, such as antiaircraft guns or ships engines, are first given a skeleton of tape. A thick solution of vinyloid type is then sprayed in the form of cobwebs interlacing to form a fine webbed structure. Over this several

heavy coats of vinyloid, usually in emulsion or latex form are sprayed leaving a thick, tough durable film fitting exactly to the contour of the object. Within this casing silica gel or other water absorbent is placed and it is expected that material so protected can be put in use very rapidly if need arise. This has been termed Operation Zipper, or Operation Mothball, and is now consuming a large share of the vinyloid plastics and solvents for them. One of the products employed is a copolymer of vinylidene chloride, $H_2C:CCl_2$, and acrylonitrile — both being vinyloid in character.

The acrylic and more particularly the homologous methacrylic esters form a large family of polymers of this type. Their use for molding powders far outshadows their coating importance, but this is steadily growing. The most useful products are propyl, butyl and similar methacrylates, polymerized, and soluble in hydrocarbons. They give air-dry, colorless films of better than average resistance to moisture, salt, alcohol, dilute acids and alkalis, etc. They make a popular type of clear metal lacquers for silver, brass, etc. Under high heat they tend to depolymerize and volatilize cleanly from the surface.

Styrene is potentially one of the most abundant and cheapest plastics. As a molding powder and as a constituent of synthetic rubber it has found enormous production and use. As a coating it has little application so far, but it can be expected that more work will bring it into the field. As for its copolymer with butadiene, or divinyl as it could be called, the use as a rubber substitue is enormous while the coating applications are comparatively minor. Here we have a potentially chemical resistant surface that will also resist impact and abrasion. Deposition from solution is not practical, but lining processes have been developed and synthetic rubber as well as natural rubber must be considered among the corrosion-resistant plastics. In this class must also be notably considered the polymerized chlor-butadienes, which are superior in most chemical resistance.

The allyl phathalate resins offer interesting properties. The allyl group is a homolog of vinyl, and we have parallel compounds based on allyl chloride, allyl acrylete and even allyl-starch ether. The allyl phathalates form a link between the thermosetting alkyds and the themoplastic vinyls, in that the film when baked to its upper limit loses thermoplasticity and becomes a very hard, adhesive and chemically resistant coating. The chief potential use may be in can linings but as more users become familiar with this recently developed polymer further expansion of its field is probable.

Also a recent development are two resins based on ethylene. Polymerized ethylene gas is a white solid which may be molded or sheeted. It has extraordinarily high chemical and moisture resistance, being unattacked by alkalis, salts or mineral acids at ordinary temperatures. Only such extreme agents as concentrated sulfuric acid and nitric acid at 212° F. affect it materially. Its solubility is extremely low, but it swells and softens under aromatic and chlorinated hydrocarbons at elevated temperatures. Its value as a surface coat-

ing depends thus on finding a method of application. For some purposes it can be used as sheet or tape as a lining, but a more general method of considerable interest has just been published. This uses the plastic as a fine powder which is sprayed through an oxypropane or oxyacetylene flame. The material goes through too fast to actually melt, but is softened enough to sinter to the surface, while passing the flame over the surface causes final fusion of a continuous, non-porous and highly resistant coating suitable for plating tanks, chemical reactors and other products where maximum corrosion resistance is required.

The other ethylene plastic, on which very little information is yet available, is the polymer of tetrafluoroethylene, CF_2:CF_2. This approaches an inorganic compound in formula, and resembles them in heat and chemical resistance. It is reported to be stable at temperatures around 500° F. and to be resistant to all chemicals and solvents. If so insoluble, the only possible methods for using its inertness would be as above, or possibly in organosol form. However, in such different materials as the silicones and the polyethylene plastics we are beginning to achieve a chemical resistance and a thermal-stability of the order of inorganic compounds. In fact the resistance of some of these to hydrofluoric acid makes them superior to glass, while vinyloid materials are highly resistant to the aqua regia that dissolves such noble metals as gold and platinum. Recent data indicate that only not metallic sodium or fluorine gas affect this plastic.

We have, as this brief outline indicates, a wide field of choice for our coatings to control corrosion. The final selection depends, as initially mentioned, on several factors of which chemical resistance is only one. Each problem requires its own evaluation, and in any event the engineer should explore the possibility of using materials of intrinsic integrity before deciding on a vulnerable metal that requires protection. In fact, the object of technology should be to develop corrosion-proof metals, or suitable replacements in other structural materials, that will not require coatings. Glass, porcelain, stainless steel, monel metal are a beginning. Meanwhile, the laboratories are providing a wider and wider range of protective material to use until metallurgy perfects its products, and the need for corrosion-resistant coatings is over.

Discussion of Paper on Chemical Corrosion Resistance of Lead*

By Dr. H. H. Uhlig
Massachusetts Institute of Technology, Cambridge, Massachusetts

THE LIST of chemicals under "Chemical Corrosion Resistance of Lead" in the December number of CORROSION was probably intended as a general introductory guide for prospective users of lead equipment. Without doubt the list is useful in helping to avoid the more obvious misapplications of lead in the design of chemical equipment. There is one serious omission, however, that the reader should know about. This concerns the general caution required in employing lead or lead alloy equipment of any kind in the food and beverage industries.

For example, the list contains the following information about ethyl alcohol: "Alcohol, ethyl — no effect on lead." From this statement, and in the absence of further detail, one might assume that grain alcohol can be distilled without special consideration of such factors as the toxicity of lead-corrosion products. From the standpoint of life of lead equipment in contact with ethyl alcohol there can be no question that lead is durable, but from the standpoint of toxicity of a small amount of lead continuously going into solution, the situation requires a quite different interpretation.

As long ago as the early 1700's, it was recognized that the use of lead coils and still heads for the distillation of rum was attended by serious reactions to the health of those consuming the final product, quite apart from understandable effects attributable to rum itself. Benjamin Franklin writing to Benjamin Vaughan in 1786 writes as follows:

"I recollect that — we had some conversation on the bad effects of lead taken inwardly; and that at your request I promised to send you in writing the particular account of several facts then mentioned to you, of which you thought some good use might be made. I now sit down to fulfill that promise.

"The first thing I remember of this kind was a general discourse in Boston, when I was a boy, of a complaint from North Carolina against New England rum, that it poisoned their people, giving them the dry belly-ache, with a loss of the use of the limbs. The distilleries being examined on this occasion, it was found that several of them used leaden still heads and worms, and the physicians were of the opinion that the mischief was occasioned by that use of lead. The legislature of Massachusetts thereupon passed an act prohibiting, under severe penalties, the use of such still heads and worms thereafter." (Quoted from "Benjamin Franklin's Autobiographical Writings," page 671, Carl Van Doren, Viking Press, 1945.)

* Original paper, prepared by Lead Industries Association, published in Corrosion, Vol. II, No. 6, 330-333, December, 1946.

Not only can continued doses of small amounts of lead cause outward symptoms as Franklin relates, but attended by probably equal danger is the cumulative nature of lead poisoning such that the ingestion of small amounts over long periods, seemingly without effect at the time, may nevertheless cause eventual grave breakdown in health. This fact strongly suggests the inadvisability of using lead piping to carry potable water under *any* circumstances. Certainly the use of lead pipe in soft water districts should definitely be discouraged. The recorded cases of illness and death from constant drinking of water conveyed in lead pipe adequately speaks for a blanket condemnation of lead so applied. Furthermore, one should consider that a water normally declared safe for lead piping may change its pH during certain seasons resulting in an increased corrosion rate to a dangerous degree, or a water softener may be installed which can without question render such water unsafe for lead piping.

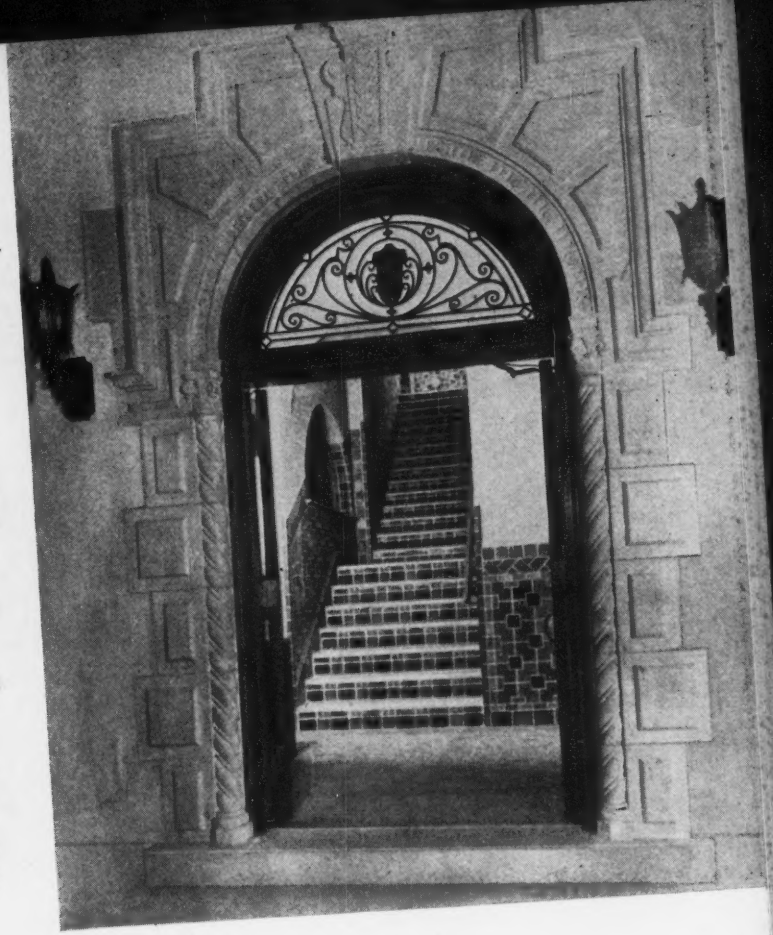
In any list of chemicals that can or cannot be used with lead, mention should also be made that carbonated beverages are not at any time to come in contact with lead equipment because of the relatively high rate of lead contamination. The action is sufficiently pronounced so that areas of lead-tin solder exposed to the liquid should be diligently avoided in order to eliminate the possibility of serious solution of lead from such solder. For example, although tin pipe is often used for carbonated waters, the use of lead-tin solder for joining is common and this has been found to be a source of lead in carbonated waters conveyed by tin piping.

In any list of chemical engineering specifications the toxicity of metal corrosion products is a vital consideration. With lead it is especially important because of the serious consequences to health that minute quantities can exert especially over a prolonged period of time.

Although dangers attending the use of lead for drinking water or foodstuffs has been known for many years, as Franklin's letter indicates, the danger is periodically forgotten or ignored, and the facts again reviewed only when some serious accident compels it. The situation today is not unlike that in Franklin's time, as expressed in Franklin's letter to Benjamin Vaughan (1786), quoted above: "You will see by it that the opinion of this mischievous effect of lead is at least sixty years old; and you will observe with concern how long a useful truth may be known and exist before it is generally received and practised on."

☆

NACE



All-Corrosion Show Section

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CHICAGO

Palmer House, April 7-10

Eight Technical Symposiums, Exhibition Feature 1947 NACE All-Corrosion Program

THE PROGRAM for the third annual NACE All-Corrosion Conference and Exhibition, which this year will be held April 7 through 10 at the Palmer House in Chicago, has been completed.

This year, for the first time, the entire proceedings of the Association, together with the Exhibition, will be held under one roof.

In the course of the well-filled, four-day program, which cross-sections and holds up for study the latest developments in the field of corrosion research and control, the Exhibition will feature almost every known method to prevent Nature's never-ceasing attempt to restore all metallic substance to the original crude.

Thirty-four technical papers will be presented during the eight symposiums on the program. Two symposiums will be held each morning, starting at 9 o'clock, except Wednesday, when two sessions are also scheduled during the afternoon, starting at 2 o'clock.

The meeting will get under way Monday, April 7, with registration set at 9 a.m., and the formal opening of the Exhibition Hall at 10 a.m. In the afternoon, the General Assembly will be called to order at 2 o'clock by F. J. McElhatton, Panhandle-Eastern Pipe Line Co., Kansas City, Mo., President of the NACE. H. H. Anderson, Shell Oil Company, Houston, Texas, and Tom L. Holcombe, Dearborn Chemical

Company, Shreveport, La., will be guest speakers. At 4 p.m., following directly the General Assembly, a business meeting for members will be held.

Tuesday morning four papers will be presented dealing with corrosion problems in the Water Industry. Resistance of aluminum alloys, and cathodic protection of water tanks and structures will be among the subjects on which papers will be presented. A general paper, "Corrosion Costs in the Water Industry," will be presented by Harry E. Jordan, Secretary of the American Water Works Association, New York. Concurrently, listeners at the Chemical Industry session will be apprised of the latest developments in that field.

Wednesday morning the Communication and Oil Industry symposiums are scheduled. During the afternoon papers will be presented during the Electrical session covering such subjects as effects of atmospheric corrosion on the economics of guy strand and line hardware; cathodic protection for lead cable sheath, and use of pulling grease as a corrosion preventive. At the same time, in another meeting room, papers will be heard pertaining to corrosion attack upon metal structures used in the gas industry. In the evening, the annual banquet of NACE will be held in the Main Ballroom of the Hotel, at which time Mr. McElhatton, the retiring president, will introduce the new officers of the association.

During the final day of the Conference, technical sessions will include papers on the problems confronting industry in general, covering food contamination, stress-corrosion, metal fatigue, thermogalvanic corrosion, inhibitors, embrittlement, metal testing and inspection, ferrous and non-ferrous metals, and allied subjects kindred to control and mitigation of the destroyer—corrosion.

Tom L. Holcombe is chairman of the General Committee, which was charged with arranging this year's all-corrosion Conference and Exhibition program. R. B. Mears, manager of the Tin Plate Research Laboratory of Carnegie-Illinois Steel Corporation, Pittsburgh, Penna., is chairman of the Technical Program Committee, which arranged for speakers for the technical sessions; and Arthur Smith, Jr., Dow Chemical Company, Midland, Michigan, headed the Exhibits Committee.

F. J. McELHATTON, President NACE

PROGRAM *National Association*

THIRD ANNUAL CONFERENCE, EXHIBITION

Monday, April 7

9:00 A.M.—Registration.

10:00 A.M.—Formal Opening of Exhibition.

2:00 P.M.—General Assembly.
Main Ballroom, Palmer House.

"Opening Address," F. J. McElhatton, Panhandle-Eastern Pipe Line Company, Kansas City, Mo., President NACE.

"A Challenge to the Corrosion Engineer," H. H. Anderson, Shell Oil Company, Houston, Texas.

"On the Other Side of the Fence," Tom Holcombe, Dearborn Chemical Company, Shreveport, Louisiana.

4:00 P.M.—General Business Meeting.
Members only. Main Ballroom, Palmer House.

Tuesday, April 8

9:00 A.M.—Water Industry Symposium.
Room No. 14, Palmer House.

V. V. Kendall, chairman, National Tube Company, Pittsburgh, Pennsylvania.

1. Effects of Various Waters on Aluminum. R. H. Brown and D. W. Sawyer, Aluminum Company of America, New Kensington, Pennsylvania.
2. Corrosion Costs to the Water Industry. Harry E. Jordan, American Water Works Association, New York, New York.
3. Treatment of Water in Army Supplies in New England. G. P. Loschiavo, 419 Elm Road, Ambridge, Pennsylvania.
4. Cathodic Protection of Hot Water Tanks. J. M. Bialosky, Armour Research Foundation, Chicago, Illinois.

TOM L. HOLCOMBE, Chairman
General Program Committee

Tuesday, April 8

9:00 A. M.—Chemical Industry Symposium. Red Lacquer Room, Palmer House.

N. E. Berry, chairman, Servel, Incorporated, Evansville, Indiana.

1. Prevention of Ferric Ion Corrosion During Acid Cleaning. J. L. Wasco, H. A. Robinson and F. N. Alquist, Dow Chemical Company, Midland, Michigan.
2. Plastics for Corrosion Control. J. W. Shackelton, E. I. duPont deNemours & Company, Incorporated, Arlington, New Jersey.
3. Corrosion Resistance of Hastelloys. C. G. Chisholm, Haynes Stellite Company, Kokomo, Indiana.
4. Effects of Different Ions on Corrosion of Aluminum. R. H. Brown and A. B. McKee, Aluminum Company of America, New Kensington, Pennsylvania.

Corrosion Engineers — CHICAGO

APRIL 7-8-9-10, 1947 — PALMER HOUSE

R. B. MEARS, Chairman
Technical Program Committee

Wednesday, April 9

9:00 A.M. — Oil Industry Symposium.
Red Lacquer Room, Palmer House.
J. M. Pearson, chairman, Sun Oil Company, Chester, Pennsylvania.

1. Arsenic As a Corrosion Inhibitor in Sulfuric Acid. A. Wachter, R. S. Treseder and M. K. Weber, Shell Development Company, Emeryville, California.
2. Silicates for Corrosion Inhibition in the Oil Industry. Wm. Stericker, Philadelphia Quartz Company, Philadelphia, Pennsylvania.
3. Cathodic Protection of Pipelines. Alan C. Nelson, Plantation Pipe Line Company, Atlanta, Georgia.
4. Effect of Carbide Structure on Corrosion Resistance of Steel. R. W. Manuel, Phillips Petroleum Company, Bartlesville, Okla.

Wednesday, April 9

9:00 A.M.—Communications Symposium.
Room No. 14, Palmer House.

Robert Pope, chairman, Bell Telephone Laboratories, New York, New York.

1. Corrosion Problems in Communications and Radio Equipment Design. L. P. Morris, Galvin Manufacturing Company, Chicago, Illinois.
2. Salt as a Medium of Corrosion of Underground Cables. A. G. Andrews, Michigan Bell Telephone Company, Detroit, Michigan.
3. Attenuation of Drainage Effects on a Long Uniform Structure with Distributed Drainage. J. M. Standring, American Bell Telephone & Telegraph Company, New York, New York.
4. Electrochemical Factors in Underground Corrosion of Lead Cable Sheath. V. J. Albano, Bell Telephone Laboratories, Summit, New Jersey.

2:00 P.M. — Gas Industry Symposium.
Red Lacquer Room, Palmer House,
A. N. Horne, chairman, Texas Empire Pipe Line Company, Tulsa, Okla.

1. Results Obtained With Pearson's Holiday Detector. A. H. Cramer and W. R. Fraser, Michigan Consolidated Gas Company, Detroit, Michigan.
2. Alloying Steels for Corrosion Resistance to Gas Condensate Fluids. K. Eilerts and Faye O. Greene, Petroleum Station, Bureau of Mines, Bartlesville, Oklahoma.
3. Statistical Analysis of Test Containers for Condensate Well Corrosion Studies. V. V. Kendall, National Tube Company, Pittsburgh, Pennsylvania.
4. Chimney Liner Corrosion Resulting from Gas Fired Furnaces. G. B. Johnson, Minneapolis Gas Light Co., Minneapolis, Minnesota.

ARTHUR SMITH, JR., Chairman
Exhibits Committee

Wednesday, April 9

2:00 P.M. — Electrical Industry Symposium. Room No. 14, Palmer House.
E. V. Sayles, chairman, Consumers Power Company, Jackson, Michigan.

1. The Electrical Engineer's Responsibility for Recognizing Corrosion as a Factor in the Design of Electrical Structures. M. C. Miller, Ebasco Services, Incorporated, New York, New York.
2. Effects of Atmospheric Corrosion on the Economics and Maintenance of Guy Strand and Line Hardware. C. J. Couy, Duquesne Light Company, Pittsburgh, Pennsylvania.
3. Corrosion Preventive Cable Pulling Lubricant for Lead Sheathed Cables in Underground Ducts. Frank Kahn and H. S. Phelps, Philadelphia Electric Company, Philadelphia, Pennsylvania.
4. Cathodic Protection of 138 K.V. Lead Sheathed Power Cables of the Los Angeles Department of Water and Power. I. C. Dietze, Department of Water and Power, Los Angeles, California.
5. A Magnesium Anode Installation for Preventing the Corrosion of Lead Cable Sheath. H. A. Robinson and R. L. Featherly, Dow Chemical Company, Midland, Michigan.

Wednesday, April 9

7:30 P.M.—Annual NACE Banquet. Main Ballroom, Palmer House, F. J. McElhatton, president of NACE, presiding.

a. Introduction of new officers.

b. An Engineering Approach to the Problems of Freedom. Edwin Vennard, Middle-West Service Company, Chicago, Illinois.

Thursday, April 10

9:00 A.M.—General Industry Symposium. Room No. 14, Palmer House.
F. L. LaQue, chairman, International Nickel Company, New York, New York.

1. The Use of Inhibitors in Corrosion Control. Norman Hackerman, University of Texas, Austin, Texas.
2. Oxidation of Stainless Alloys. James T. Gow, Battelle Memorial Institute, Columbus, Ohio.
3. Thermogalvanic Corrosion. R. M. Buffington, Servel, Incorporated, Evansville, Indiana.
4. Non-Destructive Methods of Determining Metal Plate Thickness. J. G. Kerley, Shell Oil Company, New York, New York. (Original paper prepared in collaboration with B. G. Crane, formerly of Ethyl Corporation, New York.)
5. Guide to Selecting Corrosion-Resistant Materials. L. G. Vande Bogart, The Crane Company, Chicago, Illinois.

9:00 A.M.—Cathodic Protection Symposium. Red Lacquer Room, Palmer House.
R. H. Crowe, chairman, Stanolind Pipe Line Company, Tulsa, Oklahoma.

1. Aluminum Galvanic Anodes. Part I. Laboratory Tests. R. A.

Hoxeng and R. H. Brown, Aluminum Company of America, New Kensington, Pennsylvania.

Part II. Field Tests. Ellis Verink, R. A. Hoxeng, and R. H. Brown, Aluminum Company of America, New Kensington, Pennsylvania.

2. The Determination of Pipe Protection by the Continuous Polarity Method. Wm. E. Huddleston, Huddleston Engineering Company, Bartlesville, Oklahoma.
3. Selection and Location of Anode Systems for Cathodic Protection. D. B. Good, Texas Pipe Line Company, Tulsa, Oklahoma.
4. Electrical Measurements in Cathodic Protection. J. M. Pearson, Susquehannah Pipe Line Company, Philadelphia, Pennsylvania.

COMMITTEE MEETINGS

SUNDAY, APRIL 6

2:30 P.M.—Executive Committee.

7:30 P.M.—Board of Directors.

MONDAY, APRIL 7

9:00 A.M.—Technical Practices Committee.
R. B. Mears, chairman, Carnegie-Illinois Steel Corp., Pittsburgh, Pennsylvania.

10:00 A.M.—Condensate Well Committee.
W. F. Rogers, chairman, Shell Oil Corporation, Houston, Texas.

Galvanic Anode Committee.
M. C. Miller, chairman, Ebasco Services, Inc., New York, New York.

Publications Committee.
Dr. Ivy M. Parker, chairman, Plantation Pipe Line Company, Atlanta, Georgia.

5:30 P.M.—Committee on Relations with Other Technical Societies.
F. L. LaQue, chairman, International Nickel Company, New York, New York.

TUESDAY, APRIL 8

9:00 A.M.—Regional Management Committee.
Geo. B. McComb, chairman, Barrett Div., Allied Chemical & Dye Corp., New York, New York.

Policy and Planning Committee.
H. M. Trueblood, Bell Telephone Laboratories, New York, New York.

WEDNESDAY, APRIL 9

9:00 A.M.—Membership Committee.
Tom L. Holcombe, chairman, Dearborn Chemical Company, Shreveport, Louisiana.

5:00 P.M.—Editorial Correspondents.
NACE Journal, Corrosion.
Dr. Ivy M. Parker, Editor, Plantation Pipe Line Co., Atlanta, Georgia.

THURSDAY, APRIL 10

2:00 P.M.—Board of Directors.

Adjournment.

AMERICAN COORDINATING COMMITTEE ON CORROSION

Will Hold Meeting in Conjunction with NACE Conference and Exhibition at 2:00 P. M. Tuesday, April 8

Corrosion News Section

PERSONALS

Homer D. Holler, Westinghouse Research Laboratories, rejoined the Underground Corrosion Section of the National Bureau of Standards in January. During his former association with the Bureau, Dr. Holler conducted field and laboratory studies of corrosion in soils, as well as investigations in the field of electrochemistry.

H. J. French has been appointed assistant vice-president of the International Nickel Company of Canada, Ltd. Mr. French had been assistant manager of the Development and Research Division of International Nickel since 1943. Previously he had been in charge of the Company's Alloy Steel Department. He joined International Nickel in 1929, as a member of the Research Laboratories at Bayonne, N. J.

T. C. Tweedie has been appointed manager of the Sub-Surface Department, Gulf Coast Division, Houston, Texas, of the Oil Well Supply Company.

Harold F. Ormston has resigned as supervisor of the Transportation and Material Distribution Section of the Humble Oil Production Department, to enter the transportation business. Mr. Ormston and his associates purchased the Hill & Hill Truck Line, Houston, Texas, of which Mr. Ormston will serve as manager.

Dr. L. A. Mikeska, Chemical Division of Standard Oil Development Company, has been named senior research associate. The new title, which will also be given to others who merit it, is to establish a system to give greater recognition to noteworthy technical achievements by the staff of Standard Development Co., E. V. Murphree, executive vice-president in charge of research, stated. Dr. Mikeska received the title award for his work on the structure of hydrocarbons. He has been with the company since February, 1930. He graduated from the University of Texas with a B.A. in chemistry and mathematics in 1913, and an M.A. in chemistry in 1914. He received his Doctor's degree at Yale in 1917. He remained at Yale several months as an instructor, and also taught briefly at Tulane, before joining Standard.

Harry N. Stamper, construction engineer for the Humble Oil & Refining Company's Production Department, Houston, Texas, has been named assistant chief civil engineer of that department. Another change in Humble's Production Department elevated F. K. Sawyer from assistant gas plant chief clerk for the Katy Gas Cycling Plant, to District Chief Clerk at the Pledger Natural Gas System, Danciger, Texas.

GENERAL INTEREST

At the January meeting of the NACE Executive Committee, held in Chicago, the following officers for 1947-48 were nominated:

G. E. Olson, President.
F. L. LaQue, Vice-President.
O. C. Mudd, Treasurer.

Mr. Olson, presently vice-president of NACE, is associated with the United Gas Pipe Line Company, Shreveport, Louisiana. Mr. LaQue, who if elected, will vacate his unexpired term as a director representing the Active Membership, is a member of the International Nickel Company, New York, while Mr. Mudd, of the Shell Oil Pipe Line Company, has served as treasurer of the Association since its inception.

Other officers nominated are:

Mars G. Fontana, Ohio State University, Columbus, Ohio, three-year term as director representing Active Membership, succeeding Guy Corfield, Southern California Gas Company, term expired.

H. H. Anderson, Shell Pipe Line Corp., Houston, Texas, three-year term as director representing Corporate Membership, succeeding L. G. Vande Bogart, Crane Company, Chicago, Ill., term expired, and Tom L. Holcombe, Dearborn Chemical Company, three-year term as director representing Associate Membership, succeeding M. L. Jacobs, Jacobs Wind Electric Co., Minneapolis, Minn., term expired.

H. M. Trueblood, Bell Laboratories, New York, was named chairman of the Policy and Planning Committee, succeeding Stephen P. Cobb, who resigned due to business pressure.

Appointment of a director to fill Mr. LaQue's unexpired two-year term as a director representing the Active Membership will be held in abeyance pending confirmation of his nomination as vice-president by vote of the membership.

A. H. Horne, Texas-Empire Pipe Line Co., Chairman of the Board of Trustees of the South Central Regional Division of NACE, announced that at a meeting of members of the Association, held recently in Tulsa, Okla., those present voted to form a Local Section, and elected the following officers: D. B. Good, Section Chairman, Texas Pipe Line Company; R. L. Bullock, Vice Chairman, Interstate Oil Pipe Line Co.; Yale Titterington, Secretary-Treasurer, Dowell, Incorporated.

W. G. Ainsley, Sinclair Refining Company, has been named as one of the eight members of the Society of Automotive Engineers' Technical Board for 1947. His appointment is for three years, in accordance with SAE regulations.

F. L. LaQue, chairman of the NACE Committee on Relations with Other Technical Societies, has called a meeting of that group Monday evening, April 7, during the NACE Conference and Exhibition. The time has been set for 5:30 p.m., and the meeting place will be arranged for and posted on the hotel bulletin boards. According to Mr. LaQue, the following members are expected to be in attendance: H. H. Anderson, Shell Pipe Line Corp., Houston, Texas; T. S. Bacon, Lone Star Producing Co., Dallas, Texas; Ray Hadley, Susquehanna Pipe Line Company, Philadelphia, Penna.; T. G. Hieronymus, Kansas City Power & Light Co., Kansas City, Mo.; Mr. H. E. Jordan, American Water Works Association, New York, N. Y.; J. T. MacKenzie, American Cast Iron Pipe Co., Birmingham, Ala.; R. B. Mears, Carnegie-Illinois Steel Corp., Pittsburgh, Penna.; M. S. Northup, Standard Oil Development Co., Elizabeth, N. J.; A. V. Smith, 1617 Pennsylvania Blvd., Philadelphia, Penna.; F. N. Speller, 6411 Darlington Road, Pittsburgh, Penna.; J. Strauss, Vanadium Corporation of America, New York, N. Y.; Kenneth Tator, Industrial Lining Engineers, Inc., Edgeworth, Penna.; A. W. Tracy, American Brass Company, Waterbury, Conn.; H. H. Uhlig, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.; L. G. Vande Bogart, Crane Company, Chicago, Illinois; A. Wachter, Shell Development Company, Emeryville, Calif.; B. B. Wescott, Gulf Research & Development Co., Pittsburgh, Penna.

Johns-Manville Corp., New York has begun construction of the second and main unit of its research center at Bound Brook, New Jersey. The first unit, a plant for water filtration and waste processing, has been completed. The second unit consists of a three-story, 350x67-foot research building and a 288x100-foot mechanical and service building.

South Carolina Power Company, Charleston, S. C., is planning a $9 million improvement program, according to J. F. Crist, vice president of the company.

Texas Gulf Sulphur Co., Liberty, Texas, will construct a $2 million plant, to include office buildings, machine shops, power plant and other buildings 16 miles from Liberty, Texas. Contracts for the work have been awarded.

McCarthy Chemical Co. plans construction of a chemical plant at Winnie, Texas. The first unit of the plant, which will produce unsaturated hydrocarbon chemicals, will be constructed at a cost of $3 million, according to Glenn H. McCarthy, president of the company.

Virginia Power & Electric Co., Richmond, Va., has awarded contracts for the construction of a power plant on the Potomac River, near Quantico, Va. The installation will cost an estimated $7,500,000.

Stanolind Pipe Line Co. plans construction of approximately 480 miles of 12-inch screw-joint oil pipeline between Wamsutter, Wyo., and Rangely, Colo., which will cost about $18 million, according to B. C. Clardy, Tulsa, Okla., president of Stanolind.

Geographical Roster, Membership of NACE

Supplemental listing of new members added between December 15, 1946 and February 15, 1947

CALIFORNIA

EMERYVILLE

Treseder, Richard S.
Shell Development Co.
4560 Horton St.

Weber, Martin K.
Shell Development Co.
4560 Horton St.

LOS ANGELES

Alexander, L. J.
Southern California Water Co.
1206 S. Maple Ave.

Ashline, Robert R.
Dept. of Water & Power, City of Los Angeles
207 S. Broadway

Blohm, Clyde L.
The Fluor Corp., Ltd.
2500 S. Atlantic Blvd.

Caldwell, Isaac P.
Allied Supply Co.
2068 E. 37th St.

Dod, A. Bayard, Jr.
Phelps Dodge Copper Products Corp.
611 Garfield Ave.

Gilbert, T. H.
Southern California Gas Co.
Box 3249, Terminal Annex

Hough, F. A.
Southern Counties Gas Co. of California
810 S. Flower St.

Jenkins, Vance N.
Union Oil Co. of California
617 W. Seventh St.

Stephens, Foster M.
The Fluor Corp., Ltd.
2500 S. Atlantic Blvd.

MARTINEZ

Effinger, R. T.
Shell Oil Co., Inc.
Martinez Refinery

PASADENA

Blackburn, Duncan A.
Water Dept., City of Pasadena
100 N. Garfield Ave.

SAN FRANCISCO

Pell, Duncan C. III
The Plasticoat Co.
683 Harrison St.

WILMINGTON

Artese, S. J.
Shell Oil Co., Inc.
Box 728

Dunham, R. A.
Union Oil Co. of California
Wilmington Refinery

Hall, R. E.
Union Oil Co. of California
Wilmington Refinery

COLORADO

COLORADO SPRINGS

Hagius, Karl S.
Colorado Interstate Gas Co.
Box 1087

DENVER

Burnett, Graydon E.
Bureau of Reclamation
Denver Federal Center

DISTRICT OF COLUMBIA

WASHINGTON

Donnelly, Robert M.
Strategic Air Command Hdqtrs.
Andrews Field

ILLINOIS

ARGO

Flourmoy, R. W.
Development Engineering Dept.
Corn Products Refining Co.

CHICAGO

Bradbury, J. E.
The Crane Co.
836 S. Michigan Ave.

Erickson, E. T.
Dearborn Chemical Co.
310 S. Michigan Ave.

Fletcher, Mark D.
Illinois Bell Telephone Co.
215 W. Randolph St.

Lane, Russell W.
National Aluminate Corp.
6216 W. 66th Pl.

Stobie, John J., Jr.
Apex Smelting Co.
2537 W. Taylor St.

Shelves, Arthur R.
Walles Dove-Hermiston Corp.
105 W. Adams St.

Waber, James T.
Corrosion Research Laboratory
Illinois Institute of Technology
3300 S. Federal St.

WOOD RIVER

Plovanich, Paul P.
Shell Oil Co., Inc.
Box 262

INDIANA

MONROEVILLE

Fowler, James A., Jr.
Panhandle Eastern Pipe Line Co.
Box 7

VALPARAISO

Blaese, Arnold C.
Box 129

IOWA

COUNCIL BLUFFS

Gilbert, A. A.
National Co-Operative Refinery Co.
Box 539

KANSAS

PLAINVILLE

Blazer, H. L.
Cooperative Pipe Line Assn.

LOUISIANA

LAKE CHARLES

Hargroder, A. D.
Mathieson Alkali Works

BATON ROUGE

Tuthill, Arthur H.
Standard Oil Co. of N. J.
Louisiana Division

NEW ORLEANS

McKain, G. D.
The California Co.
1818 Canal Bldg.

SHREVEPORT

Jordan, Raymond C.
United Gas Pipe Line Co.
Box 1407

Barrow, D. M.
Arkansas Fuel Oil Co.
Slattery Bldg.

SULPHUR

Griffin, James P.
Union Sulphur Co.

MARYLAND

ANNAPOLIS

Basil, John L.
U.S.N. Experiment Station
Box 685

MASSACHUSETTS

CAMBRIDGE

Uhlig, H. H.
Corrosion Laboratory
Massachusetts Institute of Technology

MICHIGAN

DETROIT

Kendall, Earl H.
Consumers Power Co.
212 W. Michigan Ave.

Nielsen, Claudius
Nielco Laboratories
8129 Lyndon St.

JACKSON

Sayles, E. V.
Consumers Power Co.
212 W. Michigan Ave.

MIDLAND

Justin, Frank H.
The Dow Chemical Co.

Kirk, E. L.
The Dow Chemical Co.

MINNESOTA

MINNEAPOLIS

Frederickson, Hubert M.
Montana-Dakota Utilities Co.
831 Second Ave.

MISSOURI

ST. LOUIS
Lester, Charles B.
Sohio Pipe Line Co.
407 N. Eighth St.

MONTANA

GLENDIVE
Schroth, Harry A.
Products & Transmission Office
Montana-Dakota Utilities Co.

NEW JERSEY

BELLEVILLE
Le Febvre, Fabian J.
Electro Rust-Proofing Corp.
1 Main St.

CAMDEN
Eddison, Clifford
Radio Corp. of America

HARRISON
Pratt, Ward E.
Chemical Section
Worthington Pump & Machinery Corp.

NEWARK
Carmichael, Elwood T.
Public Service Electric & Gas Co.
80 Park Place

WEEHAWKEN
Alfke, C. J.
Hackensack Water Co.
Christ, George J.
New York Telephone Co.
101 Willoughby

NEW YORK

BROOKLYN
Christ, George J.
New York Telephone Co.
101 Willoughby St.
Shaw, William E.
Research Laboratory
National Lead Co.
105 York St.

ITHACA
Stillman, DeWitt S., Jr.
Sigma Phi Place
Cornell University

NEW YORK
Johnston, Howard E.
Dearborn Chemical Co.
205 E. 42nd St.
Peabody, A. W.
Ebasco Services, Inc.
2 Rector St.
Scarola, V. J.
Eastern Sales & Service Eng.
4413 Gunther Ave.
Taylor, Thomas A.
American Telephone & Telegraph Co.
195 Broadway
Trueblood, Howard M.
Bell Telephone Laboratories, Inc.
463 West St.
Woody, Charles L.
Ebasco Services, Inc.
2 Rector St.

NIAGARA FALLS
Kershner, Daniel C.
Alox Corporation
Box 556

OHIO

CLEVELAND
Heil, Carl E.
Heil Process Eqpt. Corp.
12901 Elmwood Ave.

COLUMBUS
Kretschmer, William J.
Columbia Engineering Corp.
99 N. Front St.

OKLAHOMA

TULSA
Avey, Dan M.
Alox Sales Co.
Box 1914
Lavery, Charles A.
National Tank Co.
Drawer 1710
Munneke, A. S.
Stanolind Pipe Line Co.
Box 591
Oakes, Tyrus G.
Texas Pipe Line Co.
Box 2420
Texter, H. G.
Spang-Chalfant Division
National Supply Co.
National Bank of Tulsa Bldg.

PENNSYLVANIA

AMBRIDGE
Loschiavo, George P.
419 Elm Rd.

BETHLEHEM
Frye, S. C.
Bethlehem Steel Co.

COATESVILLE
Powers, William J.
Lukens Steel Corp.

EAST PITTSBURGH
Camp, Eldridge K.
Research Laboratories
Westinghouse Electric Corp.

HARRISBURG
Tracey, Edw. J. J., Jr.
Aircraft-Marine Products, Inc.
323 S. Cameron St.

NEW KENSINGTON
McKee, Arvil B.
Research Laboratories
Aluminum Co. of America

PHILADELPHIA
Anderson, H. Bruce
Philadelphia Gas Works Co.
1300 N. Ninth St.
Eaches, Albert R.
Philadelphia Electric Co.
Sixth & Chestnut Sts.
Hamilton, Hugh L.
Keystone Pipe Line Co.
Buffalo Pipe Line Co.
260 S. Broad St.
Miller, Carl F.
Susquehanna Pipe Line Co.
1608 Walnut St.
Turner, C. D.
Wailes Dove-Hermiston Corp.
401 N. Broad St.

VILLANOVA
Nelson, T. Holland
Nelson Research Laboratories

TEXAS

DALLAS
Boatright, Byron B.
Republic Natural Gas Co.
1501 Federal St.

HOUSTON
Brendel, Robert O.
The Crane Co.
2205 McKinney Ave.
Smith, Thad
Bridgeport Brass Co.
Box 2103
Waldrip, H. E.
Gulf Oil Corp.
Drawer 2100

KINGSVILLE
Dotterweich, Frank H.
Texas College of Arts and Industries

PORT NECHES
Roden, Harry
The Texas Company

TEXAS CITY
Morris, H. E.
Monsanto Chemical Co.

UTAH

SALT LAKE CITY
Littreal, William B.
Utah Oil Refining Co.
Box 898
Wheatlake, B. K.
Dearborn Chemical Co.
1414 Wilson Ave.

WISCONSIN

CUDAHY
Cooper, William C.
Geo. J. Meyer Mfg. Co.

Foreign

CANADA

CALGARY, ALBERTA
Kellam, G. D.
Canadian Western Natural Gas, Light, Heat & Power Co.
215 6th Ave. W.

KINGSTON, ONTARIO
Godard, H. P.
Aluminum Laboratories, Inc.
Box 84

ENGLAND

LONDON
Strachan, John F.
Anglo-Iranian Oil Co., Ltd.
Britannic House, Finsbury Circus

PALESTINE

HAIFA
Whalley, W.
Iraq Petroleum Co., Ltd.
Box 309

Corportae Members

	Representative
Cameron Iron Works, Houston, Texas	Jack W. Harris
Shell Pipe Line Corp., Houston, Texas	H. H. Anderson
International Nickel Company, New York, N. Y.	F. L. LaQue

Changes in Address

Changes Received Between December 15, 1946, and February 15, 1947

ARKANSAS

LITTLE ROCK

Callahan, V. L.
Southern Acid & Sulphur Co., Inc.
Box 991

CALIFORNIA

LOS ANGELES

O'Leary, F. J.
308 S. Clark Drive

Kartinen, Ernest O.
811 W. Seventh St.

COLORADO

DENVER

Chadwick, H. M.
Armco Drainage & Metal Products Co
Box 2170

DELAWARE

WILMINGTON

Crane, B. G.
Petroleum Chemicals Division
Organic Chemicals Dept.
E. I. du Pont de Nemours & Co.

FLORIDA

GAINESVILLE

Kimmel, Albert L.
Engineering & Industrial Experimental Station
University of Florida
Box 2368, University Station

GEORGIA

ATLANTA

Cauthen, H. W.
Georgia Power Co.
127 Butler St. S.E.

ILLINOIS

KANKAKEE

Higgins, Waldo W.
A. O. Smith Corp.
655 S. Harrison Ave.

KANSAS

WICHITA

Stephens, E. H.
Westinghouse Electric Corp.
301 S. Market St.

LOUISIANA

SHREVEPORT

Besse, C. P.
The California Company
Canal Bldg.

MASSACHUSETTS

QUINCY

Mosher, L. Malcolm
Bethlehem Steel Corp.
Shipbuilding Division

MISSOURI

VALLEY PARK

McGrue, W. M.
Hensler-McGrue-Lane
Route 1

NEBRASKA

BEATRICE

Krueger, Jess J.
Northern Natural Gas Co.
1708 Grand St.

NEW JERSEY

ELIZABETH

West, C. H.
Standard Oil Development Co.
Box 37

NEW YORK

BROOKLYN

Bermann, Morton
Brooklyn Union Gas Co.
197 St. James Pl.

BRONXVILLE

Schultz, Wayne H.
Hill, Hubbel & Co. Division
General Paint Corp.
1342 Midland Ave.

LONG ISLAND CITY

Staiti, J. J.
General Chemical Co.
Box 149

NEW YORK

Sample, Clarence H.
International Nickel Co.
67 Wall St.

Van Houten, Leslie P.
American Telephone & Telegraph Co.
100 William St.

OHIO

CINCINNATI

Marx, Paul F.
Williams Bros. Corp.
1821 Kinney Ave.

CLEVELAND

Heil, Carl E.
Heil Process Equipment Corp.
12901 Elmwood Ave.

MT. VERNON

Koenig, E. A.
Cooper-Bessemer Corp.

OKLAHOMA

TULSA

Bardsley, Bo
Crutcher-Rolfs-Cummings
Box 2398

OKLAHOMA CITY

Carmichael, J. D.
Electro-Rust-Proofing Co.
Box 3737

Ewing, Scott P.
Research Laboratory
Carter Oil Co.
Box 801

Harrison, Scott J.
Metal Goods Corp.
Box 2519

Luster, Gaines
Barrett Division, Allied Chemical & Dye Corp.
403 S. Indianapolis St.

Menaul, Paul L.
Research Library
Stanolind Oil & Gas Co.
Box 591

Secrest, William F.
Barrett Division, Allied Chemical & Dye Corp.
403 S. Indianapolis St.

PENNSYLVANIA

JEANETTE

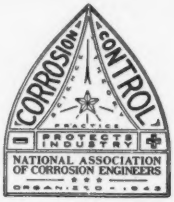
Holler, H. E.
Westinghouse Electric Corp.
Research Laboratories
R.F.D. 1

SOUTH CAROLINA

GREENVILLE

Bull, Irving Stuart, Jr.
Engineering Dept.
Dunean Mills

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS



is a non-profit, scientific and research association of individuals concerned with, and/or interested in corrosion, whose objects are:

(a) To promote scientific research in determining the causes of corrosion and methods of its control with respect to theory and practice.

(b) To provide a means of exchange of knowledge and ideas among those individuals actively engaged in corrosion research and control.

(c) To promote methods of control of corrosion.

(d) To promote standardization of terminology, methods, equipment and design in the development of methods of corrosion control.

(e) To foster cooperation between individual owners of metallic structures in the solution of their joint corrosion problems.

Inquiries regarding membership are solicited. A bona fide interest in corrosion control and mitigation, and/or research are the essential qualifications. For the convenience of those persons desiring to become members of the association, membership applications appear on the following pages. Fill in the required information, tear out and mail to the Executive Secretary at the administrative headquarters,

National Association of Corrosion Engineers
905 Southern Standard Building
Houston 2, Texas

When completed, tear out blank and mail to the Secretary of the NACE at the office of the Association, 905 Southern Standard Building, 711 Main Street, Houston 2, Texas.

Application for Admission as (Active / Junior) Member

No._____

to

The National Association of Corrosion Engineers

To the Membership Committee:

Full Name_____
(Please Print)

associated with_____

business address_____ Street

_____ City_____ State

position_____

1. Years engaged in corrosion work_____
2. Education, General and Technical_____
3. Corrosion Experience_____

The undersigned certifies that the above statements are correct and hereby makes application for admission to the National Association of Corrosion Engineers and agrees to pay annual dues in accordance with those set forth in the By-Laws for the grade to which admitted.

The undersigned requests that the first $3.00 of his current year's Association dues be applied as a subscription, at members' rate, to the magazine CORROSION for the calendar year for which such dues are paid.

_____

Signature and residence address _____

Date_____ 19____

☐ Enclosed_____ ☐ Please render Bill.
(Check, Money Order, Payable to Association)

MEMBERSHIP

Membership in the Association is open to all individuals actively engaged in the development, design, installation and/or operation of equipment used for the control of corrosion.

EXTRACTS FROM THE ARTICLES OF ORGANIZATION

Article III

Section 2. An Active Member of this Association shall be an individual who is actively engaged in research concerning corrosion, or who is actively engaged in the development, design and installation of equipment or methods used for the control of corrosion, or the operation and maintenance of structures subject to corrosion.

Section 3. A Junior Member shall be a student or any otherwise qualified person engaged or interested in the advancement of knowledge relating to corrosion control. At the time of his admission he shall be not less than 18 years of age. His connection with the Association shall cease when he becomes 25 years of age, *unless* he is regularly enrolled as a student in a university or has previously transferred to the grade of Active Member. Junior Members shall receive official publications distributed to members and shall have all privileges of Active Membership except those of holding office and voting.

EXTRACT FROM BY-LAWS

Article II

Section 1. Each Active Member shall pay annual dues of Seven Dollars Fifty Cents ($7.50).

Section 2. Each Junior Member shall pay annual dues of Two Dollars Fifty Cents ($2.50).

Section 5. Annual dues shall be payable in advance and shall be due on January 1st of each calendar year.

When completed, tear out blank and mail to the Secretary of the NACE at the office of the Association, 905 Southern Standard Building, 711 Main Street, Houston 2, Texas.

Application for Admission as (Active / Junior) Member

No._____

to

The National Association of Corrosion Engineers

To the Membership Committee:

Full Name_____
(Please Print)

associated with_____

business address_____ Street

_____ City_____ State

position_____

1. Years engaged in corrosion work_____
2. Education, General and Technical_____
3. Corrosion Experience_____

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_____

Signature and residence address _____

_____

_____

_____

Date_____ 19____

☐ Enclosed_____ ☐ Please render Bill.
(Check, Money Order, Payable to Association)

MEMBERSHIP

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Article III

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Section 3. A Junior Member shall be a student or any otherwise qualified person engaged or interested in the advancement of knowledge relating to corrosion control. At the time of his admission he shall be not less than 18 years of age. His connection with the Association shall cease when he becomes 25 years of age, *unless* he is regularly enrolled as a student in a university or has previously transferred to the grade of Active Member. Junior Members shall receive official publications distributed to members and shall have all privileges of Active Membership except those of holding office and voting.

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Section 5. Annual dues shall be payable in advance and shall be due on January 1st of each calendar year.

When completed, tear out blank and mail to the Secretary of the NACE
at the office of the Association,
905 Southern Standard Building,
711 Main Street, Houston 2, Texas.

Application for Admission as (Corporate / Associate) Member*

No._____

to

The National Association of Corrosion Engineers

To the Membership Committee:

Name_____
(Company, Corporation or other organization)

Business address_____Street

_____City_____State

Principal Product_____
(If Association, state objectives)

Representative_____

Position or title_____

Mailing address_____

The undersigned certifies that the above statements are correct and hereby makes application for admission to the National Association of Corrosion Engineers and agrees to pay annual dues in accordance with those set forth in the By-Laws for the grade to which admitted.

The undersigned requests that the first $3.00 of his current year's Association dues be applied as a subscription, at members' rate, to the magazine CORROSION for the calendar year for which such dues are paid.

Signature, title and address _____

Date_____19____

☐ Enclosed_____ ☐ Please render Bill.
(Check, Money Order, Payable to Association)

*Membership Classification to be determined by the Executive Committee, National Association of Corrosion Engineers.

The National Association of Corrosion Engineers is duly incorporated under the Laws of the State of Texas as a non-profit association with full powers to engage in the types of business and pursuits as set forth in the Articles of Organization and By-Laws.

EXTRACTS FROM THE ARTICLES OF ORGANIZATION

Article III

MEMBERSHIP

Section 1. Membership in this Association shall be of four (4) classes: Active, Junior, Corporate, and Associate.

Section 4. A CORPORATE MEMBER shall be any company, corporation, utility, association, board, commission, department (State, County, Municipal, Federal) or other body or organization engaged or interested in corrosion and corrosion control. Corporate Members are restricted to those who do not primarily produce and sell equipment or materials for the purpose of control or mitigation of corrosion and shall be entitled to one representative whose name shall appear on the roll of members and who shall have all the rights and privileges of an Active Member. This representative may be changed at the convenience and pleasure of the Corporate Member on written notice to the Secretary.

Section 5. AN ASSOCIATE MEMBER shall be any company, corporation or other body or organization engaged in the production or sale or both of equipment or materials for the purpose of control or mitigation of corrosion. An Associate Member shall be entitled to one representative whose name shall appear on the roll of members and who shall have all the rights and privileges of an Active Member. This representative may be changed at any time at the convenience and pleasure of the Associate Member on written notice to the Secretary.

EXTRACT FROM BY-LAWS

Article II

Section 3. Each CORPORATE MEMBER shall pay annual dues of one hundred dollars ($100.00).

Section 4. Each ASSOCIATE MEMBER shall pay annual dues of one hundred dollars ($100.00).

Section 5. The fiscal year of the Association shall begin on January First, and terminate on December Thirty-First. Annual dues shall be payable in advance, and shall be due on January 1st in each year. It shall be the duty of the Secretary to notify each member on or before December Thirty-First in each year of the amount due from said member for the ensuing year.

Section 6. Any newly elected member shall be entitled to all of the publications of the Association that are distributed to its members during the year, or that part of the year, for which he has paid dues.

Corrosion Abstracts

ATMOSPHERIC CORRSION

Attack of Various Atmospheres on Copper and Some Copper Alloys at Elevated Temperatures. A. P. C. HALLOWES AND E. VOCE, Based on 1st half of BNFMA Report RRA 527, Metallurgia, **34**, No. 200, 95-100 (1946) June.

Copper and copper alloys tested included: Three high-conductivity and two arsenical copper; six aluminum bronzes, forming a group of alloys of high-scaling resistance; a group of alloys containing small amounts of common elements added individually to copper (including three percent nickel); and Everdur, Kuprodur (0.5 percent silicon and 0.7 percent nickel), and a 5 percent tin-0.1 phosphorus-copper alloy. The materials were tested for resistance to oxidation and scaling at 400° C. in: 1) dry air freed from acid impurities; 2) same air plus 10 percent water vapor; 3) ditto plus 0.1 percent sulfur dioxide; 4) ditto plus 5 percent sulphur dioxide, and 5) plus moist hydrogen chloride. Tables and graphs give fullest report of data. Conclusions included: 1) aluminum bronzes were most resistant, but all additions except silver helped; 2) addition of water vapor made little difference to scaling rates, but some materials showed decreased attack; 3) presence of sulfur dioxide increased attack; 4) small amounts of moist hydrogen chloride accelerated scaling markedly, only aluminum bronzes and silicon alloys showing moderate resistance; 5) selective oxidation by Price and Thomas method protected 5 percent aluminum bronze from atmospheric oxidation up to 800° C., but did not help when atmosphere contained sulfur dioxide or hydrogen chloride; 6) on the whole, arsenical coppers were less attacked than the others, and the presence of aluminum conferred highest resistance, while the silicon alloys gave generally good results.

Weathering Behavior of Corrosion-Resistant Steel Insect Screens. W. A. WESLEY AND H. R. CORPSON, International Nickel Co., ASTM, Preprint **1946**, No. 52, 1-14.

Results of several series of atmospheric corrosion tests are presented in which commercially woven wire-cloth screens of bronze, 18 percent chromium, 8 percent nickel corrosion-resistant steel and type 316 corrosion-resistant steel were exposed in sulfurous, industrial, marine, and rural atmospheres. Type

18-8 corrosion-resistant steel wire cloth is too susceptible to pitting if partly sheltered from rain in industrial and marine atmospheres to outlast bronze similarly sheltered. Type 316 steel screens show phenomenal resistance to corrosion in industrial atmospheres whether sheltered or not and will long outlive bronze screens. Molybdenum content should be high. Other advantages of type 316 corrosion-resistant steel insect screens over bronze screens include freedom from staining of white paint, high strength, clearer vision, and greater ease of cleaning.

Atmospheric Corrosion Tests of Corrosion - Resistant Steel Wires. A. P. JAHN, Bell Telephone Labs., ASTM, Preprint, **1946,** No. 49, 3 pp.

Report on atmospheric corrosion tests of 12-14 percent chromium and 18-8 stainless steel wire exposed for four years in severely and mildly industrial seacoast and rural exposures. No marked corrosion of wire has been noted yet, and tensile tests after 4.9 years and 8.5 years exposure showed no significant changes in tensile strength or elongation. Farm, field and chain link fences are mentioned.

Results of 15 Years' Exposure Tests on Corrosion-Resistant Steels. I. V. WILLIAMS AND K. G. COMPTON, Bell Telephone Labs., ASTM Preprint, **1946,** No. 53, 5 pp.

Results of exposure of ten corrosion-resistant steels to N.Y.C. atmosphere for 15 years are reported. Steels varied in content as follows: carbon 0.062 - 0.46 percent, nickel 0.04-23 percent, chromium 8.60-18.66 percent. Loss in tensile strength was small. Thirteen percent chromium steels showed considerable surface rust. Type 18-8 and 17 percent chormium steels rusted slightly. Full data given.

Corrosion of Ferrous Materials. C. P. LARRABEE, Steel, **119,** 134 (1946) Sept. 9.

Results of tests reported before annual meeting of ASM indicate that corrosion rate is mainly dependent upon length of time surface is moist; amount and nature of atmospheric contaminants; and composition of steel.—BLR.

BOILER CORROSION

Boiler Auxiliaries. EEI Prime Movers Subcommittee Report 1944-45. Combustion, **17,** No. 11, 45 (1946) May.

Summary of results of a survey among operating companies and pump manufacturers with reference to boiler feed-pump corrosion - erosion is given. Many of the trouble-free installations used stainless-steel pumps, and there was no case of failure from corrosion-erosion when 5 percent chromium or higher was used for pump parts. Many companies eliminated trouble by installing alloy-steel parts, or depositing alloy-filler metal on carbon parts. The study indicated that: 1) black ferrous oxide is more easily eroded away from metal surface than red ferric oxide; 2) high pH value is most favorable, providing it is due to a definite alkaline salt addition rather than to presence of transient ammonia; 3) pumps rotated in service under water conditions which develop a red ferric oxide coating have a better record than those operated continuously, the reverse being true where a black oxide coating

exists; and 4) where the sulphite condition of boiler water exceeds 5 to 10 ppm there is a tendency to break down. Percentage of failure with heads over 300 psi per stage was the same as that in which the stage pressure was less than 200 psi, indicating that stage pressure by itself is not a factor in evaluating potential corrosion-erosion troubles.

Corrosion in Cast-Iron Sectional Boilers. E. R. WALTER, J. Inst. Heating & Ventilating Engrs., **13,** 285-304 (1946); Chem. Abs., **40,** No. 20, 6044 (1946) Oct. 20.

The use of brine-free coal will eliminate the formation of hydrogen chloride. Water, a by-product of combustion, must be kept as steam and carried off with the other gaseous products. For this reason, every portion of the heating surface must be kept above 106° F. Discussions included.

Boiler Tube Failures. V. WALKER, Elect. Times, **108,** 696-699 (1945); Brit. Abs., **BI,** 118 (1946) Apr.

Failure may be due to defects in the tubes caused by laminations or folds in the tube wall, inclusion of dirty metal slag or other non-metallic substances, eccentric bore, and improper heat-treatment. Fracture by overheating may be due to low water level in the boiler, presence of obstructions, accumulation of scale or sludge, or uneven absorption of heat. Internal corrosion may arise from the presence of oxygen or the contamination of the feedwater with acid. External corrosion has occurred on the furnace wall tubes of dry and slagging bottom furnaces where intense flame impingement on furnace walls keeps the slag fluid. Further causes of failure are internal cracking due to alternate overheating and cooling of the inside wall of the tube, and external cracking, which is found mostly on heavy-gauge tubes, particularly when lanced with water and air or water and steam. External erosion is caused by the sandblasting effect of ash particles in the gases and by entrained water in the steam from spot blowers. Embrittlement cracking of tube ends, where they are rolled in drums or headers, is due to a high caustic in the capillary spaces between the tube and the tube seat.

CATHODIC PROTECTION

Galvanic Couples and Cathodic Protection. M. C. MILLER, Ebasco Services Inc., Petr. Eng. **17,** No. 8, 55-58 (1946) May.

A series of tests was conducted on buried pipes of different metals, arranged to permit correlation of galvanic currents, pipe-to-soil potentials over anodic and cathodic areas, and effects of increments of cathodic protection current on galvanic currents and pipe-to-soil potentials. Discussion here is limited to the relationship of galvanic couples to cathodic protection current and potentials, but some of the other effects are shown on the charts.

Magnesium as a Galvanic Anode. Some Factors Affect Its Performance. H. A. ROBINSON, Dow Chemical Co., Electrochem. Soc. Birmingham, Apr. 11-13, 1946. Electrochem. Soc. Preprint 90-4.

The performance characteristics of the magnesium anode have been studied with regard to the effects of such variables as current density, anode composition, impurities, elec-

trolyte pH, and electrolyte composition. It was found that the potential of the magnesium anode is sufficient for cathodic protection of pipelines, storage tanks, process equipment, etc., with most naturally occurring electrolytes, and that both the anode current efficiency and the uniformity of anode consumption improve with increasing current density. High purity magnesium-aluminum and magnesium-aluminum-zinc alloys perform more efficiently than commercially pure magnesium. Saturated solutions of calcium sulfate or magnesium sulfite provide the most generally satisfactory electrolytes for magnesium anode operation.

Use of Magnesium for Cathodic Protection of the Katy Pipe Line. P. HART AND O. OSBORN, Petr. Eng., **17**, 136 (1946) Aug.

Highly successful application of magnesium for cathodic protection of the Dow Chemical Company's Katy pipe line on the Texas Gulf Coast should be of exceptional interest to the corrosion engineer. Cathodic protection as a weapon in the great battle against corrosion has always been an intriguing subject to all engineers. Now after six years of extensive investigation, magnesium beckons as a new and deadly ammunition for this weapon. The Katy line is a 4-inch coated line, 82 miles in length, extending inland from the Dow Chemical Company's Freeport plant to the Humble Oil and Refining Company's plant, 33 miles west of Houston, Texas. This article shows how 96 magnesium anodes installed in 14 groups were employed in obtaining cathodic protection of this line.—GPC.

Electrolytic Corrosion — Methods of Evaluating Insulating Materials Used in Tropical Service. B. H. THOMPSON AND K. N. MATHES, Gen. Elec. Co., Paper for AIEE, Winter Tech. Mtg. N. Y., Jan. 22-26, 1945; Electrical Eng. **64**, No. 6, 295-299 (1945) June.

Moisture conditions in the tropics are described, and means for producing such conditions in the laboratory are considered. The visual, corrosion-current, and water-extract conductivity methods for studying electrolytic corrosion are given. Typical results for a number of different insulating materials used in electrical devices are given.

CHEMICAL CORROSION

Corrosion Resistance of Duralumin, Aciéral, Iron and Sheet Steel to Palm Oil. DISY AND CHAPHEAU, Bull. matiéres grasses inst. colonial Marseill, **28**, 39-40 (1944); Chem. Abs., **40**, 5387-5388 (1946) Sept. 20.

Duralumin and Aciéral were not affected after five months at 150° F. in crude palm oil. Iron and sheet steel showed traces of corrosion after the second week. Tests at 64° for 200 hours in crude palm oil and boiling methyl alcohol at 125° for 120 hours in boiling isoamyl alcohol, at 160° for 72 hours in cyclohexanol, and at 190° for 36 and 30 hours in decahydronaphthalene are also reported.

New Alloys for Severe Corrosion Services. M. G. FONTANA, Ohio State Uni., Chem. Eng. **53**. No. 10, 114-115 (1946) Oct.

Compositions, mechanical properties, and corrosion resistance information on Duriron's two new alloys, Chlorimet 2 and 3, are presented in

condensed form. These high nickel alloys (60-63 percent Nickel, 18-32, molybdenum, 0-18 percent chromium, 0.15-0.07 percent carbon) are suitable for handling all concentrations of sulfuric and hydrochloric acids, wet chlorine, sodium chloride, hot acetic acid, bleach solutions, etc. Recommended heat treatment is heating at 2,050° F. for one hour per inch of thickness, and then water-quenching. Graphs show corrosion of Chlorimet 3 versus heat treatment, and exposure time in boiling three percent sulfuric acid; corrosion of Chlorimet 3 versus heat treatment and hydrochloric acid concentration (158° F. aerated); corrosion of Chlorimets 2 and 3 versus concentration of sulfuric acid (176° F. aerated); hardness of Chlorimet 2 versus aging time, aging temperature and carbon content; corrosion of nickel-molybdenum-chromium alloys (variations of Chlorimet 3) versus heat treatment and composition in 5 percent hydrochloric acid plus 0.5 percent nitric acid, 158° F. aerated. Tensile strength, yield strength, elongation, Brinell hardness, quench-annealed and aged, are tabulated, as well as corrosion of Chlorimet 2 by hydrochloric acid after various heat treatments.

Passivation of Stainless Steel. E. M. MAHLA AND N. A. NEILSSEN, E. I. du Pont de Nemours & Co. Paper before Electrochem. Soc., 89th Gen. Mtg., Birmingham, April 10-13, 1946. Electrochem. Soc., Preprint **89-27**, 319-341 (1946) Apr. 15.

The strength and stability of passive films on stainless steel are evaluated. Break-through-potential data and confirmatory immersion - corrosion data showed that no passivation treatment confers lasting protection to stainless steel immersed in media which corrode the unpassivated metal. Equally effective results were obtained with stainless steel which was cleanly pickled, thoroughly rinsed, and air dried. Although no definite evidence of the existence of passive films was found by reflection electron diffraction studies, bulk oxides produced by chemical or air oxidation on 18-8-S stainless steel were found to consist chiefly of chromic oxide, with no nickel oxide and little iron oxide present. The bulk oxides formed by air oxidation on straight chromium-iron alloys consisted of FeO, Fe_3O4, Fe_2O_3, and mixtures of these oxides.

Modified Chromic Acid Anodizing Process for Aluminum. C. J. SLUNDER AND H. A. PRAY, Battelle Memorial Inst., Ind. & Eng. Chem., **38**, No. 6, 592-596 (1946) June.

A wartime shortage of chromic acid made necessary a study of chromic acid anodizing by a process in which bath maintenance is achieved by sulfuric acid additions. The sulfate content of such baths introduces corrosion difficulties when steel tanks are used. However, with protected tanks and carbon cathodes and by controlling the operation on the basis of anode current density, the process appears from the laboratory test to offer promise of considerable saving in chromic acid consumption. The relations between current density, voltage, sulfate content, and coating weight are described.

Corrosion of Steel by Gaseous Chlorine. G. HEINEMANN, F. G. GARRISON AND P. A. HABER, Southern Alkali Corp. Ind. & Eng. Chem., **38**, No. 5, 497-499 (1946) May.

Data are presented on the rate of corrosion and ignition temperature of mild sheet steel in commercially dry chlorine gas at temperatures from 77° to 251° C., for exposure periods between 12 to 480 minutes. Gradual increase in corrosion rate are noted as the temperature is raised to 248° C. At 251° C., the sheet steel coupons show a greatly accelerated corrosion rate of approximately 31 inches penetration per year (170,000 mg. per sq. dm. per day) for exposure periods of less than 30 minutes. After 30-minute exposure at 251° C., the sheet steel coupons ignite, to give corrosion rates in excess of 170,000 mg. per sq. dm. per day. Graphs, tables, tests and equipment are shown.

On the Corrosion of Condenser Tubes Accompanying the Removal of Scale. I. S. KATSEN, Korroziya i Bor'ba s Ney, **7,** 14-22 (1941) (In Russian) J. Inst. of Metall. Abs. **13,** 209 (1946) June.

Brass condenser tubes are not attached in solutions of solium hexametaphosphate. Brass is strongly corroded in soda solutions which are used for softening incrustations. In cleaning condenser tubes in acids, parts made of steel or cast iron are attached, being anodic in the brass-iron couple. Complete protection of condenser plates and tubes is obtained by paint or lacquer coatings and by the use of steel protectors.

Corrosion of Metals by Methanol. A. GUILLEMIN, Ann. Chem., **19,** 145-201 (1944) Brit. Abs., **BI,** 108 (1946) J. Inst. of Met. & Metall. Abs. **13,** 211 (1946) June.

The rate of corrosion in the presence of air and at 18-25° C. for aluminum, copper, tin, lead, zinc, cadmium, antimony, bismuth, chromium, iron, nickel and columbium in anhydrous methanol, methanol containing 20 percent of water and 2 percent of formaldehyde, and 1 percent of formic acid in methanol and water is reported.

Corrosion and Stability Studies. F. BELLINGER, H. B. FRIEDMAN, W. H. BAUER, J. W. EASTES AND W. C. BULL, Chem. Warfare Sv., Edgewood Arsenal, Md., Industrial & Eng. Chem. **38,** No. 3, 310-323 (1946) Mar.

The lack of knowledge of how to handle, store and ship hydrogen peroxide of more than 50 percent concentration necessitated the studies of stability and corrosion of concentrated hydrogen peroxide and calcium permanganate as reported here. Commercial steel drums were found satisfactory for shipment and storage of permanganates. For use with concentrated (80-90 percent) peroxide, all surfaces required reconditioning by an acid wash, followed usually by a peroxide soak. After such conditioning, Pyrex, aluminum (99.6 percent plus), aluminum-magnesium alloys, tin, tantalum, cadmium, stainless steel types 304 and 316 are suitable materials on construction for process equipment; Pyrex and aluminum (99.6 percent plus) are satisfactory for storage containers. Koroseal and polyethylene are suitable for gasket materials. Silicone grease is satisfactory as a lubricant and does not affect peroxide. The stability of peroxide is an inverse function of the impurities present. Of the stabilizing agents investigated, phosphates give the best results; but above a certain concentration, addi-

tional amounts increase the rate of decomposition. Concentrated peroxide cannot be "detonated" by shock unless organic material also is present. Numerous tables are given showing the effect of material on hydrogen peroxide and calcium permanganate, including nickel, Chromel, Croloy, stainless steel 304, 410, 466 and Hastelloy.

Phosphoric Acid vs. Materials of Chemical Plant Construction — Symposium. Chem. & Met. Eng. **53,** No. 7, 221-222+ (1946) July; No. 8, 203-204+ (1946) Aug.; No. 9, 203-204+ (1946) Sept.

Symposium in which manufacturers discuss the suitability of products for phosphoric acid service, with corrosion data includes:

Carbon, Graphite, Karbate, L. C. Werking.

Chemical Stoneware, by F. E. Herstein, Gen. Ceramic & Steatic Corp.

Copper, Copper alloys, by C. L. Bulow, Bridgeport Brass Co.

Durimets T and 20, by D. E. Jacks. The Duriron Co.

Glass-lined Steel, by O. I. Charmann, The Pfaudler Co.

Hastelloy Alloys, by C. G. Chisholm, Haynes Stellite Co.

Haveg, by P. L. McWhorter, Jr., Haveg Corp.

High-Silicon Iron, by R. M. Shelds, The Duriron Co.

Illium "G," by T. E. Johnson, Burgess Parr Co.

Lead, by H. M. Church, Lead Inds. Assoc.

Nickel, Nickel alloys, by W. Z. Friend, International Nickel Co.

Rubber Lining, by O. S. True, U. S. Rubber Co.

Stainless Steel, by H. C. Esgar, Carnegie-Illinois Steel Corp.

Tantalum, by F. L. Hunter, Fansteel Metallurgical Corp.

Vitreous Silica, by W. W. Winship, Thermal Syndicate, Ltd.

Wood Tanks, by S. E. Chaney, National Wood Tank Inst.

Worthite, by W. E. Pratt, Worthington Pump Co.

Corrosion in Buttner Rotary Dryers (for Brown-Coal Briquettes). H. PIATSCHEK, Braunkohle, **43,** 289-295 (1944); Brit. Coal Util. Res. Assn., Month, Bull., **9,** 351 (1945); Brit. Abs., **BI,** 158 (1946) May.

Corrosion of the dryer was traced to oxidation of sulfurous acid. Methods of determining sulfur dioxide in the drying gas are mentioned. The trouble was remedied by using alternative constructional materials and coatings and by increasing the amount of drying gas.

Rate of Corrosion of Aluminum and on the pH of the Solution. G. V. AKIMOV AND A. I. GLUKHOVA, Inst. for Phys. Chem., Acad. Sci. USSR. Compt. rend., acad. sci., URSS, **49,** 194-197 (1945) (English summary); Chem. Abs., **40,** 4335 (1946) Aug. 10.

Rate of corrosion of aluminum in solution of sodium chloride, sodium sulfate and sodium nitrate at pH 0 to pH 14 was adjusted with sodium hydroxide or the acids according to the anion present. In the strongly acid and strongly alkaline regions the rate of corrosion is of the same order. In neutral and acid solutions, the rate of corrosion in the presence of chloride ion is as much as 1,000 times greater than in the presence of the sulfate ion. In strongly alkaline solution the rate of corrosion is

about the same in the presence of either ion. Up to pH 10, the electrode potential is positive during corrosion. Above pH 10, the potential has higher negative values, reaching — 1.3 V. at pH = 14.

Corrosion in Hydrofluoric Acid Alkylation. F. A. PRANGE AND R. A. FINDLAY, Phillips Petroleum Co. Petr. Refiner, **25,** No. 3, 85-88 (1946) Mar.

Results of tests carried on by the Phillips Petroleum Co., first designer of HF alkylation units, are reported. Rate of corrosion in aqueous and anhydrous hydrofluoric acid of various metals and alloys including Monel, cupro-nickel, silver and stainless steel is tabulated and discussed. Corrosion experience in plant operation is also discussed. Corrosion of Monel bubble caps, chimneys, trays and linings in acid rerun tower at 150-200° F. in anhydrous acid was slight. Laboratory experience indicated that corrosion rate of cupro-nickel is not affected by velocity and that it is suitable up to 200° F. for concentrated acid service. The corrosion pilot plant warned that 12 percent chromium stainless corroded rapidly in high velocity streams of anhydrous acid. Some 18-8, used for thermocouple well orifices, and trim for relief valves and diaphragm motor valves, has given satisfactory service, although it has not shown appreciably higher resistance than ordinary carbon steel. In view of costs, stainless is not considered much for hydrofluoric acid. Silver was used only where there was no chance of excessive wear or erosion, e.g., in plating relief valve springs. Monel linings, welded in strips, have a tendency to develop leaks, causing accelerated corrosion in aqueous acid service in lower section of acid rerun tower. Monel-clad steel is recommended.

Sulfur in Manufactured Gas. Its Effects Upon Dew Point of Flue Products. WILLIAM BUCKLEY, Am. Gas Assn. Monthly, **28,** 403-406 (1946) Sept.

Sulfur trioxide in flue gas raises the dew point considerably as well as producing an acid condensate. Both factors promote corrosion. Graphs show relationships of dew point, temperature, SO_2/SO_3 ratio, and sulfuric acid content. Correlates the more important findings and suggests several factors for future investigation.—BLR.

Corrosion-Resistant Alloys. Steel, **119,** 70-75, 112 (1946) July 29.

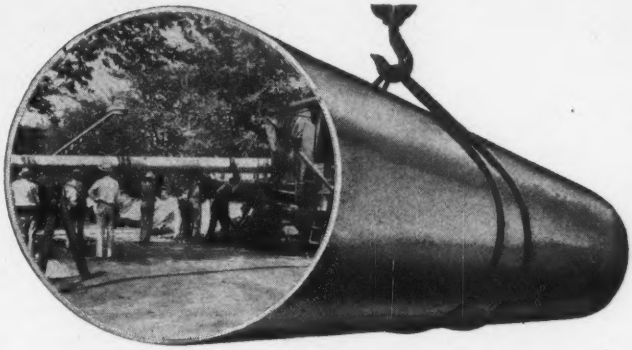
Four metals finding wide use in industries which handle such reactive acids as boiling hydrochloric, sulphuric and hot nitric are described and their range of application indicated.—BLR.

COATINGS

Plastic Coatings for Metals. BERNARD GOULD, Modern Metals, **2,** 24-25 (1946) Sept.

Describes a method for protecting metals against corrosion. Cellulose-type plastic coating provides a moisture and corrosion proof skin which can be removed simply by peeling-off. Coating material is reclaimable and transparent, or may be colored, and is easy to apply.—BLR.

Flame Sprayed Plastics. MORTON J. GURDIN. Iron Age, **158,** 64-65 (1946) Aug. 22.



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Applying Reilly Primer to 12″ pipe.

Application of various plastics by spraying finely ground powder through an oxy-propane flame is described. Characteristics of a sprayable thermo-plastic material finding wide use in the plating industry as a tank lining are discussed.—BLR.

Films and Surface Cleanliness. JAY C. HARRIS, Met. Finishing, **44,** 328-330 (1946) Aug.

Discusses surface films in relation to practical operations. Covers metal surfaces, films, corrosion, applications, and pickling. 14 references.—BLR.

Compound Rust Preventive, Thin Film. (U. S. Army Ordnance Tentative Spec. AXS-673 (Rev. 2) (10/23/45); superseding AXS-673 (Rev. 1) (6/12/43) 5 pp. Available from Office, Chief of Ordnance, Army Service Forces, Washington 25, D.C. (QH-5, A-74).

The rust preventive specified must conform to the following requirements:

Solvent content, maximum, 60 percent; Abrasives, none; flashpoint, minimum, 100° F.; flow point, none; corrosion, none.

Gel Lacquer Technique for Protective Coating. CARL J. MALM AND HAROLD L. SMITH, JR., Ind. and Eng. Chem., (Ind. Ed.), **38,** 937-941 (1946) Sept.

Application of unusually heavy protective coatings depends upon gelation of lacquer by temperature change alone, without the necessity of solvent evaporation. This behavior is obtained by proper selection and balance of the solvents. Cellulose mixed esters are suitable as bases.—BLR.

Coating to Protect Bay Bridge. Eng. News Record, **136,** No. 22, 40 (1946) May 30.

Experiments to prevent corrosion of steel members of the San Francisco-Oakland Bay Bridge include application of a zinc coat, 0.0010-inch thick, applied to 1,300 square feet of structure exposed to salt spray. A patented "gun" forces powdered zinc into a 1,600° flame, to fuse the metal to bare steel structure, prepared by grit blasting. Treatment is said to last eight or nine years, as compared with about three years for ordinary paint applications.

Films and Surface Cleanliness. J. C. HARRIS, Met. Finishing, **44,** No. 9, 386-388 (1946) Sept. (See Aug. issue also.)

Various inhibiting and passivating films are described, as well as pickling inhibitors. A table lists characteristics of the various conversion coatings, including phosphating, bluing, blackening, oxide and sulfide films, anodic and chemical finishes, and chromating on iron, steel, aluminum, brass, copper, magnesium and zinc. 14 references.

Corrosion of Cupal at Cut Edges. H. GORLACHER, Korros. u. Metallschutz, **19,** 174-176 (1943) Brit. Abs., **BI,** 183 (1946) May.

Corrosion is normally not serious, and can be reduced by (1) polishing the edges, (2) electroplating or lacquering the fabricated article, (3) suitable design of articles to avoid subjecting the edges to corrosive conditions, or (4) treatment in a boiling solution containing 5 parts sodium dichromate and 10 parts sodium carbonate in 100 parts of water. (Cupal is copper-plated aluminum.)

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Improving Corrosion Resistance on Zinc Alloy Die Castings. Die Casting, **4**, No. 5, 68+ (1946) May.

Yellow "Anozinc" coatings are being applied to valve handles used in liquefied petroleum gas valves and refrigerator valves because of the superior corrosion resistance of this surface, plus the color, which harmonizes with brass fittings. This proprietary electrolytic process is the counterpart of the anodizing process for aluminum, but is adapted to the coating of zinc with a hard durable film. A patented chromate bath solution is the basis for electrodeposition. The process is described.

Action of Antifouling Paints. Maintenance of the Leaching Rate of Antifouling Paints: Formulated with Insoluble, Impermeable Matrices. J. D. FERRY AND B. H. KETCHUM, Woods Hole Oceanographic Inst., Ind. & Eng. Chem., **38**, No. 8, 806-810 (1946) Aug.

Maintenance of the leaching rate by an antifouling paint which contains a high loading of toxic in an insoluble, impermeable matrix depends upon continuous contact of toxic particles throughout the paint film. The rate at which the leaching rate falls during extraction, as well as the total amount of toxic extractable, is sensitive to the proportion of toxic in the paint. This proportion must exceed 30 percent by volume to make particles below the surface accessible to solvent action. Antifouling coatings of this type have the advantage of being effective when applied as a thin film, with good resistance to erosion.

Rustproof Coating Survives Die-Stamping. Steel, **118**, No. 18, 155 (1946) May 6; Steel Processing, **32**, No. 5, 298-340 (1946) May.

A new rustproofing technique for steel and galvanized steel which deposits a coating of from 5 to 15 millionths of an inch, will protect stock during manufacturing stages and permit a tighter bond with paints. In the Banox process, coating consists of a glassy metal phosphate, so plastic that it will bend with the steel, or permit die-stamping without harm to the coating. Process is operated at normal temperature and requires no heat to produce a simple, effective and economical coating on steel, zinc and other metals and alloys. Four purposes are accomplished: (1) Preventing rust between cleaning and painting; (2) insuring a grease and alkali-free surface; (3) increasing durability of finish; and (4) preventing spread of rust from unprotected edges where base metal is exposed. Applied by spray, immersion or brush, steel so coated resists rusting in plant atmosphere several months. Illustrations show painted steel panels after exposure to standard salt-fog corrosion test for 300 hours at 95° F.

Plastics as Substitutes for Non-Ferrous Metals in the Textile Industry. E. A. GURKOV, Korroziya i Bor'ba s Ney, **5**, No. 5/6, 97-109 (1939) (In Russian). J. Inst. of Met. & Metall. Abs. **13**, 240 (1946) June.

Experiments on the use of anti-corrosion non-metallic coatings in the Ivanov Textile Machine-Building Works are described.

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Aluminum Dipcoated Steel — A New Material Preview. Materials & Methods, **24,** No. 1, 90-94 (1946) July; Modern Metals, **2,** No. 7, 14-16 (1946) Aug.

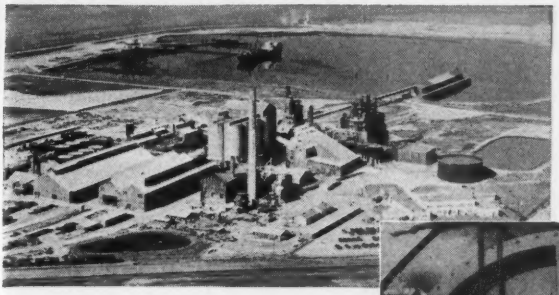
Sheet steel dipcoated with aluminum under the trade name Armco Aluminized Steel, by a continuous process patented by the American Rolling Mill Co., takes its place with tin terne, terne plate and galvanized sheet among corrosion resistant sheet materials. An aluminum film 0.001-inch thick is retained on both sides of the steel. Two finishes, dull and extra smooth, are available. Comparison of heat reflectivity of the new material with stainless steel and porcelain enamel finishes is made. Laboratory salt spray test in 20 percent salt spray at 95° F. have shown coating life of 1000 to 2000 hours, while a standard 1 ounce galvanized coating lasted only 100 to 130 hours. Samples are undergoing tests at Kure Beach. No discoloration occurs at 900° F. and in cyclic tests up to 2000° F. The material showed superior performance when used for mufflers, combustion chambers of gas-fired, air-heating furnaces, heat exchanger tubes, etc. Applications as heat deflectors for electric ranges, oven liners for kitchen ranges and coal or wood-fired ranges utilize the particular combination of heat resistance and good heat and light reflectivity. Tensile strength and yield strength, elongation and Rockwell hardness suitable for base material are given. Welding is discussed. Aluminum surface can be restored by spraying joints. This material costs twice as much as a galvanized sheet of same thickness.

Water Immersion Testing of Metal Protective Paints. W. W. KITTELBERGER AND A. C. ELM, New Jersey Zinc Co., Ind. & Eng. Chem., **38,** No. 7, 695-700 (1946) July.

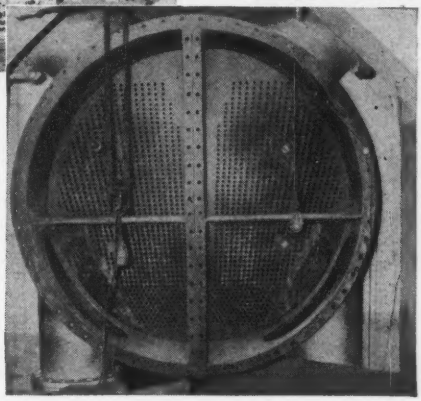
The role of osmosis in water absorption and blistering is discussed. A paint system consisting of one coat of zinc chromate primer and one coat of low gloss, alkyd hull paint was applied to various substrate materials and immersed for varying periods of time in distilled water and in solutions of sodium-chloride and sucrose with osmotic pressures of 6 to 30 atmospheres. The rate and degree of water absorption and blistering were determined by extensive measurements of weight and volume changes, and by visual examination. Regardless of the nature of the substrate and immersion bath, water absorption and blistering increased with increasing immersion time but decreased markedly with increasing osmotic pressure of the bath. The probable mechanism of the reaction is discussed.

Finish Durability Improved with Vitreous Phosphate Coating. C. T. ROLAND AND H. I. ROSENBLOOM, Calgon, Inc. Steel, **118,** No. 24, 122 (1946) June 17.

Cold, aqueous solutions spontaneously coat steel and zinc with amorphous film sufficiently plastic to withstand forming and drawing operations. Discussion includes a base for paint, adherence and flexibility, plant use, control and replenishment, degreasing the metal, coating, chemical rinse, drying and economic considerations. Graphs and painted steel panels after exposure to ASTM standard salt-fog corrosion test are shown.



Highly corrosive salt water from the Corpus Christi ship channel is the cooling medium for this condenser at the Southern Alkali Corporation plant, Corpus Christi, Texas. Anaconda Super-Nickel was selected for this retubing job because of its superior resistance to corrosion by salt water.



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Localized Surfacing Combats Wear, Corrosion. A. R. LYTLE, Union Carbide & Carbon Research Labs., Inc. Paper before AWS, 26th Ann. Mtg. Machine Design, **18,** No. 5, 131-136 (1946) May.

Localized surfacing of machine parts for increased resistance to corrosion and wear can be accomplished by metal spraying, applying preformed pieces using mechanical fastenings, by brazing or low-temperature soldering and by fusion welding. The latter is the most versatile and widely applicable method. Electric arc and flame welding for this purpose is described. Hastelloy C's remarkable usefulness in the hardfacing field is mentioned, as well as Hastelloy B and D's corrosion resistant characteristics. Typical examples are shown.

DDT as a Marine Antifouling Agent. J. F. MARCHAND, Yale Univ. Sch. of Med. Sc., **104,** No. 2691, 74-75 (1946) July 26.

Experiments testing the applicability of DDT for antifouling purposes are reported. DDT incorporated in a marine paint was found to be effective in inhibiting the development of barnacles although it does not provide effective control of other organisms which cause fouling of ship bottoms. It does not wash away in sea water over a four month period, and it retains its effectiveness when incorporated as a constituent of paint. Admixture of DDT does not appear to have an adverse effect on the drying properties or durability of the paint.

Under-Water Paints and the Fouling of Ships. J. E. HARRIS AND W. A. D. FORBES. Paper before Inst. of Naval Architects, Lond., Apr. 12, 1946; Eng. Digest, **3,** No. 6, 313-314 (1946) June.

Work of the Marine Corrosion Sub-committee of the Iron and Steel Institute and the Admiralty Corrosion Committee is reported. The Admiralty Corrosion Committee is standardizing the leaching rate test for ascertaining how the methods of manufacture, and variation in ingredients of a paint affect of the anti-fouling qualities. A study of 150 experimental paints by this method by the Marine Corrosion Sub-committee is reported, and general conclusions are summarized. The Admiralty Corrosion Committee is exploring the potentialities of the wet sandblasting process for ships, developed in the U. S. An apparatus is shown for examining the effect on corrosion of motion in sea-water, such as occurs at the surface of a ship's hull. Rotation at rate of 1,500 rpm is set up with a specimen holder, which is equivalent to a peripheral speed of 20 knots. The Chemical Research Laboratory (DSIR Teddington) uses this to carry out accelerated tests of corrosion resistance of metals and protective coatings on metals intended for use in severely corrosive environments. Information can be obtained in one-tenth the time required using non-accelerated methods of testing.

Etching for the Microscope—Part II. Non-Ferrous Metals and Alloys. C. A. E. WILKINS, Metal Treatment, **13,** No. 45, 41-52 (1946) Spring.

Description of the solution necessary to etch alloys of aluminum, copper, magnesium, nickel (Monel and nickel chromium) silver and zinc. The article reviews the etching methods most likely to produce cer-

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tain structures of bearing metals, stellite and cemented carbides. Nickel and chromium plating are discussed. Photomicrographs of alloys and tables showing etching solutions for copper and its alloys, and identification of constituents in copper and its alloys, and identification of constituents in commercial aluminum alloys are given. 12 references.

Acidic Atmosphere Evaluation of Cleaning on the Corrosion of Steel. C. W. SMITH, Detrex Corp. Paper before Electrochem. Soc. 89th Gen. Mtg., Birmingham, Apr., 1946; Electrochem. Soc. Preprint 89-25, Adv. Copy, 289-306 (1946).

The "acidic atmosphere cell" a simple accelerated corrosion test—incorporating moisture, acidic gases, oxygen, temperature variations, etc., was used to evaluate different cleaning materials and methods in regard to their effect upon the corrodibility of bright steel. Cleaning methods using either abrasives, or alkaline compounds, or volatile or partially volatile solvents, and emulsified solvents were compared as to effects on bright steel and when exposed in the "acidic atmosphere cell."

CONSTRUCTION MATERIAL

Metallurgical Requirements for Manufacture of Corrosion-Resisting, High-Strength Sheets of Aluminum-Zinc - Magnesium Alloys. W. PATTERSON, Metallwirts, **23**, 161 - 173 (1944); Brit. Abs., **BI**, 72 (1946) Feb.

High-tensile aluminum-zinc-magnesium alloys are subject to normal stress-corrosion, and to layer-corrosion in which the alloy disintegrates by flaking. These features are ascribed to the recrystallization and precipitation behavior of the alloys, which differ from those of the aluminum - copper - magnesium alloys in that the changes in properties due to dissolution and precipitation take place at 40-100° lower temperature. The effect of establishing additions of beryllium, cerium, chromium, vanadium, thorium, titantium and zirconium respectively, on the softening and recrystallization of a number of aluminum-magnesium, aluminum-magnesium-zinc and aluminum-magnesium - zinc - manganese alloys has been investigated.

Bolting for Pipe Flanges and Pressure Vessels. S. CROCKER, Detroit Edison Co., Power Plant Eng. **50**, No. 5, 75-78 (1946) May.

Some 20 years' experience with alloy-steel bolt-studs high-pressure and/or high temperature service, and with carbon steel headed bolts under less severe service conditions is reflected in ASTM specifications for pipe flanges bolts. Standards for alloy steel bolting, carbon and alloy steel nuts dimensional standards for bolts and threads are discussed. Present bolting specification combines A96, which covered three strengths of material, and left composition to customer, and A193, which contains individual requirements for composition and physical properties of each of several types of ferritic steel and 18-8. Present specification incorporates the three strength classes of A96 into A193 as additional grades, which have physical properties and draw temperatures designated but no chemical requirements. Both carbon and alloy steels are used for nuts. Where nuts are used with bolts of same composition, nuts should differ in hardness from bolts to reduce tendency for

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galling or seizure. Drift and stripping tests for nuts are described. Table gives composition and properties of carbon and alloy steel bolting material.

Refiner's Notebook—Exchanger Tubes. W. L. NELSON, Univ. of Tulsa, Oil & Gas J., **44,** No. 46, 113 (1946) Mar. 23.

Brass, steel and chromium steel tubes are used almost exclusively, although there are a few installations of copper-nickel, Inconel, nickel, Monel, Karbate (compressed carbon), tantalum and silver for conditions of extreme corrosion, mainly of a chemical nature. Copper-base alloys are poor resistors to hydrogen sulfide, so steel or chrom steel are used if oil contains or generates this. Sizes and distances between tubes are discussed. A table gives main materials, properties and temperature at which properties change. A one-page condensation.

Cooling Tower of Stainless. Sheet Metal Worker, **37,** No. 6, 50+ (1946) June.

A stainless steel cooling tower of the air conditioning system in a manufacturing plant in Connecticut, 100 by 20 by 30 feet replaces zinc of equal tonnage. The latter was abandoned, not for corrosion resistant reasons, but because of its comparative softness, causing louvers to sag. Type 18-8 was used for the interior deck plates (8 decks) as well as eliminators. Condenser systems and flow of hot water in towers are described. Tower is shown.

Corrosion Forum — Materials of Construction in Bead Catalyst Plant. E. C. FETTER, Chem. & Met. Eng., **53,** No. 5, 231-232+ (1946) May.

Materials of construction used in the bead catalyst plant of Socony-Vacuum, at Paulsboro, N. J., are described. Flow-sheet and process are also given. Three-eighths inch tellurium-lead is strapped every two feet on sides and bottom of alum reactor. Educator mixers are of bronze. The 42,000-gallon tanks handling sodium silicate and aluminum sulphate are lead-lined steel. Bronze plug, seat and rod in pressure control valve was replaced by Lucite, and stainless steel rotameter bobs by Worthite. Saran tubing and fittings are employed for connections to mixing head. Flume to wet processing tanks is of wax-coated steel. The following materials gave good service in various components of the wet processing system, in which the 10 percent alum solution for base-exchange is only corrosion solution: stainless steel (18-8) wire screen strainers over effluent liquor outlets, lead-piping and valves, bronze pumps and valves, wooden slatted platforms to support beads in tank to prevent agglomeration. Some unusual phenomena, probably dew-point corrosion, were observed in some locations where stainless steel parts in contact with saturated steam vapors would corrode whereas ordinary steel nearby was not affected. The reverse occurred in other places. Internal drains plugged with mush and bead fines so that thin slurries or gel accumulated and was picked up and sprayed on fan housings, heating coils and drier walls causing severe corrosion and erosion. Partial solution was construction of steel pans under the first five feet of each conveyor provided with external drains and lines with thin reinforced cement lining.

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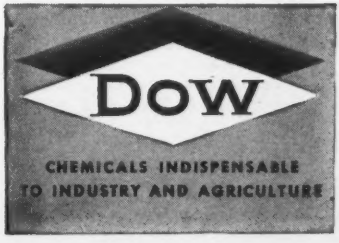

Engineering News at a Glance—Handling Cut or Corroded Rolls. Steel, **119,** No. 2, 110 (1946) July 8.

One method of handling cut or corroded rolls which are causing production lags, according to Youngstown Welding & Engineering Co. engineers, is to pressure weld covers of Monel, Inconel, nickel, stainless steel or any corrosive resisting weldable material on them. Method of welding shrinks the covers on new or old cores so the shells will fit tightly serving in many instances for years without grinding and other maintenance, yet providing a smooth, clean surface, free from pits and corrosion. Over 1,000 rolls welded in this fashion established remarkable records for long service at low cost.

Carbon-Graphite Mechanical Parts. F. F. RUHL, U. S. Graphite Co. Steel, **118,** No. 20, 108-110+ (1946) May 20.

Rings, seals, bearings, disks, blades and other parts of Graphitar (Carbon-graphite) press-molded and baked at 3000° F., stand up under extremes of speed, temperature and pressure yet possess virtues of strength, hardness, self-lubrication and light weight. Uses and properties fully described and illustrated. Compressive strength of 18,000 to 37,000 psi make it serviceable as cores in metal castings and its heat resisting qualities (oxidizes at 700° F. but does not melt or fuse at any temperature) make it useful in glass manufacture. 143 chemicals listed which do not affect or react with it.

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What Cemented Carbides Offer the Designer. R. K. Lotz, Machine Design, **18,** No. 6, 135-138+ (1946) June.

General use and properties of cemented carbides are reviewed, with specific illustrations. Physical properties of some are tabulated, including six cobalt carbides. Corrosion resistance is determined by binder or matrix metal. A summary of results from laboratory corrosion tests is given. Hydrochloric, nitric, and sulfuric acids, sodium hydroxide, ammonia, and salt solutions are discussed.

CORROSION TESTING

Laboratory Evaluation of Corrosion Resistant Pigments and Vehicles. H. Zahn, National Lead Co., Paint, Oil, Chem. Rev. **109,** No. 18, 6-9 (1946) Sept. 5.

A technique for following corrosion processes as they occur under a paint film, based upon the potential relationship of steel to hydrogen as regards corrosion of the steel or lack of corrosion attack is described. Information is presented on the development of the technique and the effect of drying time, vehicle, and surface preparation. The test is said to be of value because (1) reproducible results are easily obtainable, (2) it is sensitive to (a) vehicle and pigment used, (b) the overall paint formulation, (c) the method of surface preparation, (d) the metal surface oxide condition, (e) the chemical character of the contact solution, and (f) the thickness of the paint film.

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